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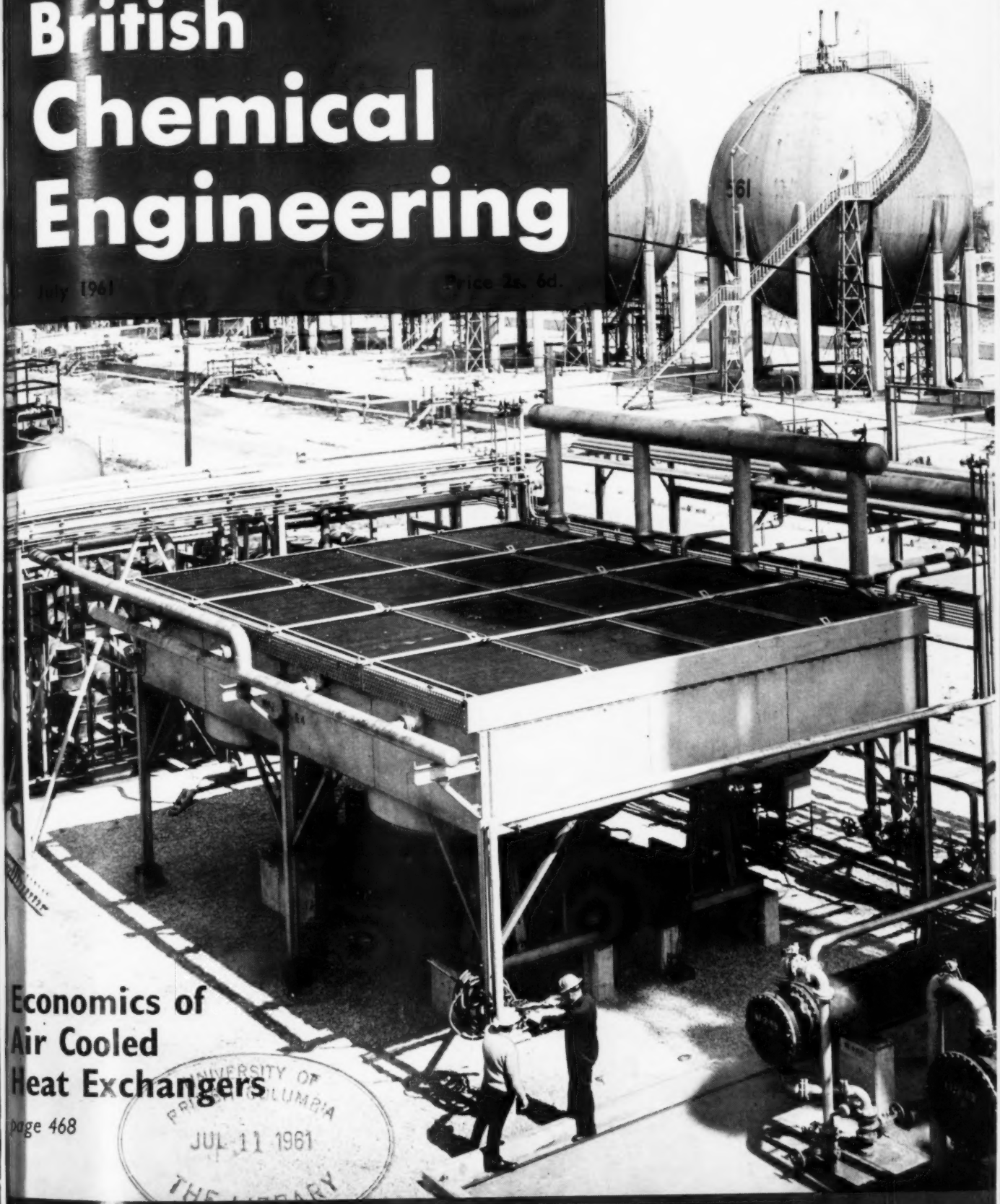

Economics of Air Cooled Heat Exchangers

page 468

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JUL 11 1961
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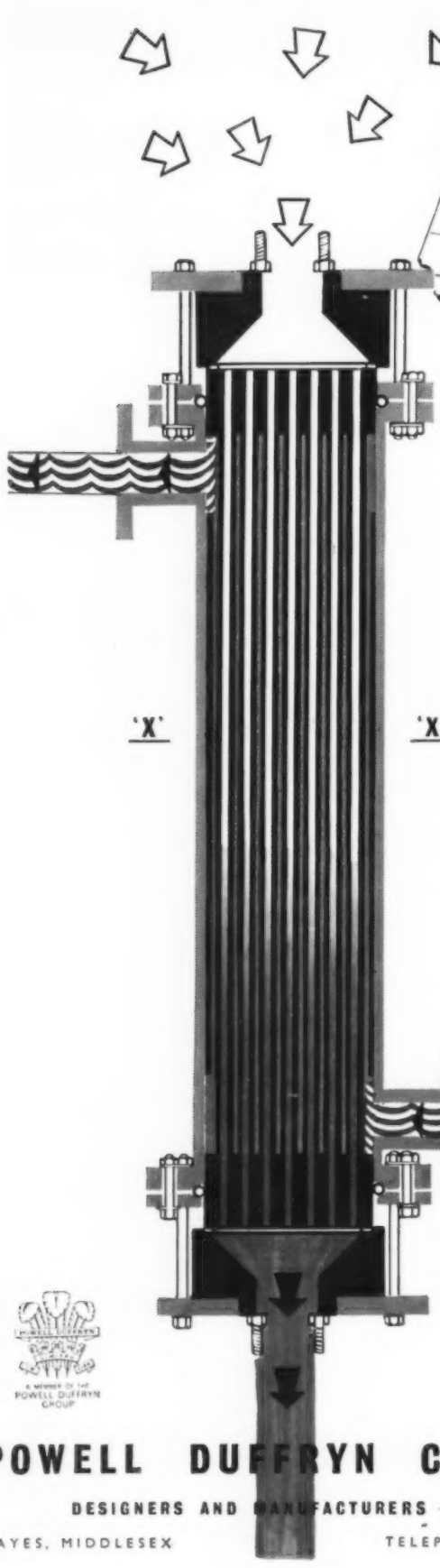
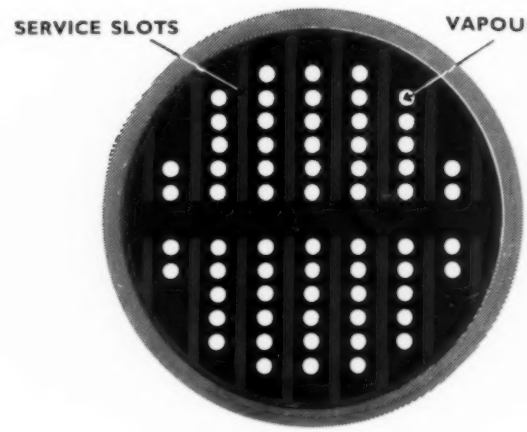
A Rectifying Column for Difficult Separations (page 459)
... and ... Remuneration in Industry (page 474)
Computers for the Chemical Engineer (page 481)

BCE 9869 for further information

High Performance Graphite Condensers.





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"Delanium" Graphite Cartridge Condensers are completely resistant to the corrosive attack of most acids, alkalis and solvents up to a maximum graphite temperature of 180 C.

Salient features of the design are its simplicity, compactness, flexibility, and robust construction giving strength and rigidity and long life combined with a heat transfer performance unequalled by any other condenser.

Cartridge units are available for heat transfer areas from 4 ft.² to 500 ft.²

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DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Problems of Continuous Pulping

CONTINUOUS methods of making pulp for the paper industry offer a challenge to the chemical engineer, according to Professor W. J. NOLAN of the Pulp and Paper Laboratory, Engineering and Industrial Experiment Station, University of Florida, speaking before a joint meeting of the American Institute of Chemical Engineers and the Chemical Institute of Canada.

Although improvements in design and instrumentation have been made over the years, the batch digesters currently in use are still primarily pressure vessels in which the operators have to fit the process to the equipment; it is extremely difficult to bring about radical changes in design or operations. For continuous high speed pulping on a commercial scale to become a reality it is necessary for chemical engineers to investigate all the problems involved and to design and prove the final process equipment.

One of the problems is very severe corrosion; in continuous processing, the liquors will be much more severe than in conventional batch pulping where maximum temperatures are 145°C. or less and where sulphuric acid concentrations have been reduced by continuous relief as pressure rises.

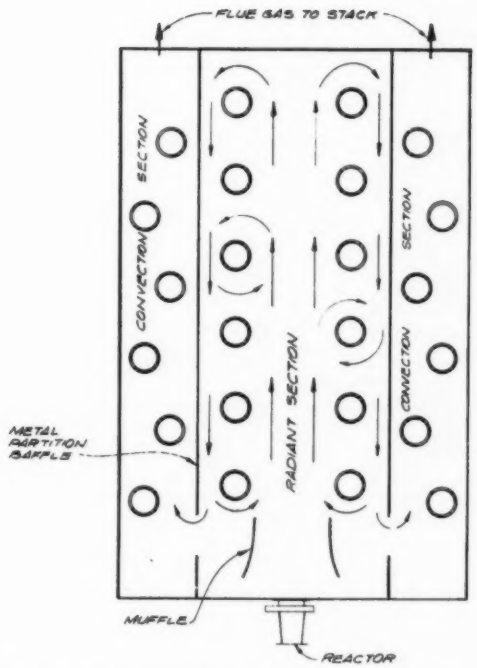
Fuel Reactor Fired Heat Exchangers

PROCESS heaters used today in the oil and petrochemical industries are mostly of the direct-fired radiant type in which the process fluid to be heated flows through tubes arranged around the walls of a combustion chamber. Fuel gas or oil is supplied to burners located in the walls, floor or roof of the chamber, and the heat to the tubes is primarily by radiation from the combustion zone.

An alternative method of heat transfer, which has been under development for the past three years, uses convective rather than radiant heat transfer. The combustion reaction is completed before the hot gases are discharged into a heat exchanger (known as Uniflux): this eliminates the slowing-down of the reaction rate due to heat transfer lowering the temperature of the reacting gases. Also, the products of combustion are discharged at high velocity into muffles to act as jet pumps and create rapid recirculation of the fuel gases around the heat exchanger tubes. By this means uniform distribution of heat absorption is obtained around each tube circumference.

The fuel reactor used with the new Uniflux heat exchanger is of the vortex type, and requires a forced air feed. The heat exchanger consists of a central section heated by recirculated fuel gas and two outer waste heat recovery sections. In the 3,000,000 BTU/hr experimental unit, three fuel reactors were used, the hot products of combustion from these being injected through the floor of the heat exchanger cabin at points 2 ft apart.

In comparison with the conventional radiant type process heater, the Uniflux method is claimed to have the



following advantages: no flame impingement on the heat exchanger; uniform heat absorpton; efficiency higher by 10-20%, amounting to as high as 90% with a heat recovery section; light weight and compact size; low noise level; greater safety in hazardous areas; suitability for intermittent operation; fast response and close control of process-heater outlet temperature; no air infiltration or outwards flue-gas leakage; higher average heat absorption rates for same maximum tube temperature; and lower process coil pressure drop for equivalent heat absorption.

A disadvantage is the power required for the combustion air blower; however, this amounts to a reduction in the overall efficiency of the heat exchanger of only 2%.

Particular advantages of the Uniflux system when used with fuel-oil firing are the reduction in formation of sulphuric acid due to less excess air and, hence, less tube corrosion and less fouling from sodium sulphate.

Instrumentation in Steelmaking

SOME of the problems in instrumentation which steelmakers come up against have been described recently before the Society of Instrument Technology by N. P. BACON and J. E. DAVIES of Guest Keen Iron and Steel Works, Cardiff.

Although the conventional lever weighbridge is very accurate when properly used, under production conditions

it is not always possible to carry out the correct procedure and for some purposes it cannot be used. Load cells, which can be used with remote recording and automatic print-out arrangement, have been used successfully for weighing ladles on cranes, measuring load in rolling mills or weighing awkwardly situated tanks. However, there is some difficulty in obtaining Board of Trade approval for such systems. Extreme care must be taken in the design of such installations to ensure that the cells are axially loaded.

Continuous measurement and automatic control of the moisture content of the sinter strand bed in a sinter plant are desirable requirements at present unattainable. Commercially available continuous moisture-content meters based on electrical capacitance methods are not suitable because the individual constituents of the sinter mix are affected in different ways by the addition of water, and when mixed together the overall effect gives no useful indication of water content.

In the melting shop, experience has shown that automatic control links must be simple—the furnace man will have the whole system back on manual operation rather than make elaborate adjustment.

Air/fuel ratio control for regulating the amount of combustion air supplied to the furnace has not been found completely adequate. A better method is the continuous sampling and analysing of the waste gas and then controlling he combustion air quantity to give a fixed percentage of oxygen in the gas.

At Guest Keen Iron & Steel Works, development of automatic furnace pressure control—essential for successful control of combustion air—is closely linked with the introduction of oxygen jetting on most of the open hearth furnaces. The scheme is that each waste heat boiler will have an induced draught fan drawing gases from the furnace and delivering them under pressure to a common exhaust duct. Furnace pressure will be automatically maintained by these fans—thus there is a possibility of interaction between furnaces.

Detailed information about the system response time and characteristics of the control units is needed to analyse the system thoroughly. Some instrument makers seem unable to supply such information in suitable form.

Other difficulties encountered concern the automatic control of furnace roof temperature by varying the fuel supply, due to spurious indications by the radiation pyrometers due to interference from flame and radiation from waste gases. Special pyrometer installations are necessary in measuring furnace roof temperature when oxygen jetting is practised.

In the rolling mills, there is increasing use of automatic control instrumentation. At the hot Morgan Mill at Cardiff, measurement of bloom weight enables the operator to adjust the flying shear position to give the most economical billet length: an array of photosensing elements determines the length of the red hot bloom approaching the mill to within $\pm$ 2 in, the figure being displayed in digital form to the flying shear operator at the other end of the mill. A further improvement under consideration is to build computer control for automatically positioning the flying shear flag for optimum billet length.

Corrosion and Fouling by Boiler Flue Gases

VARIOUS techniques for assessing the potential fouling or corrosive tendencies of boiler flue gases and their effects on the operation of a particular boiler have been collected together by the Boiler Availability Committee.* The methods described are best suited to the comparison of different operating conditions and for indicating the effects of any change that has been made.

All the tests described involve the use of a probe inserted into a gas stream, and suffer from the inherent limitations of such techniques. It is therefore recommended to sample from more than one position, preferably simultaneously, and to traverse the gas stream at each sampling point.

Two groups of techniques are described: (i) those for investigating low temperature corrosion and its causes, using the BCURA dewpoint meter, corrosion probes, sulphur dioxide and sulphur trioxide determinations, or acid deposition probe; and (ii) those intended for determining the nature and extent of high temperature fouling, for which deposition probes at present provide the only possible means. Most of the techniques described are for short-term testing, yielding results within the hour, and permitting detailed investigation of rapid changes in conditions. Some of the tests are suitable for longer-term work representing average conditions more closely, and providing an indication of the likely frequency of outages for cleaning, and repairs.

* *Testing Techniques for Determining the Corrosive and Fouling Tendencies of Boiler Flue Gases.* The Boiler Availability Committee Bulletin MC/316. March, 1961.

Automatic Continuous Weighing of Moist Solids

AUTOMATIC continuous weighing systems for moist materials which do not flow freely have been developed for output ranges 100-200, 500-1,000, 1,000-2,000 and 5,000-8,000 kg/hr by the Russian State Institute of Nonferrous Metals.* The basic system consists of two structurally independent units:—a regulating unit controlling the feed of weighed material, and a weight flow meter acting as transmitter for the control system.

To control relatively low flows of materials which do not flow freely, plate feeders have been adopted with an off-centre, vertical-walled, hopper. With this off-centre arrangement (which gives an improved static characteristic), when the blade displacement is altered in the direction of increased flow, the initial effect is a decrease in flow

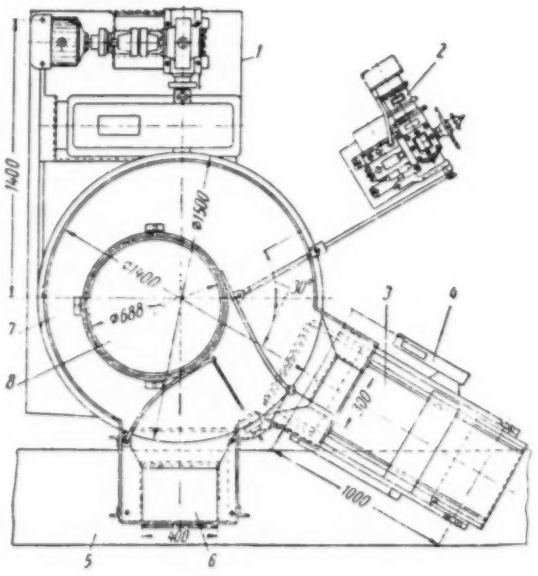


Plate feeder with an off-centre hopper. 1, *plate feeder drive;* 2, *actuator for displacing the blade;* 3, *weighing Conveyor;* 4, *weighing probe;* 5, *collecting convevor:* 6, *reserve duct;* 7, *plate;* 8, *hopper.*

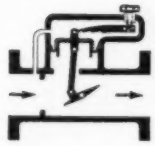
FLOSTAT PERFORMANCE

In every type of Flostat the control of fluid flow is achieved by a valve which is operated directly by the pressure differential at a metering orifice.

The Standard and Type 'V' Flostats are fitted with Flow-Balanced Double-Beat Poppet Valves: the Type 'B' Flostat has a Butterfly Valve.

Below are given typical performance curves which show clearly the different characteristics of both types of valve.

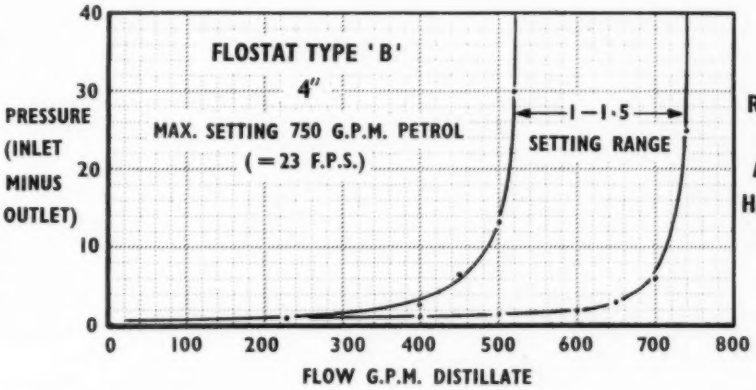
STANDARD



TYPE 'B'

THE TYPE 'B' FLOSTAT
HIGH CAPACITY FLOW GOVERNOR

The butterfly valve limits maximum flow but offers the least resistance to normal flow. Type 'B' Flostats safe-guard metering equipment and plant from surges, and prevent build-up of static charge. Made for pipe sizes:— 2½ in., 3 in., 4 in. and 6 in.



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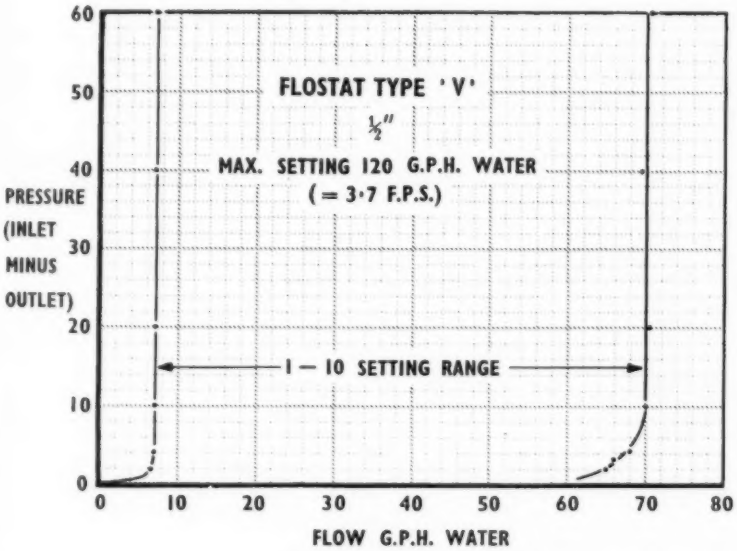

THE TYPE 'V' FLOSTAT
WIDE RANGE, HIGH ACCURACY CONTROLLER

The flow-balanced double-beat poppet valve ensures quick and accurate control. The Type 'V' Flostat is used for chemical processes of all kinds: it enables an accurately controlled flow of gas or liquid to a vessel to be adjusted to suit different process requirements. It is much used for fuel oil control because its high response speed minimises overshoot at start-up. It produces accurate control over the wide range of supply and back pressure variations likely to be encountered in emergency conditions which would cause difficulties with other types of automatic valves.

Type 'V' Flostats are made for pipe sizes:— ½ in., 1 in., 1½ in., 2 in. and 4 in.

For the accurate control of small flows the Flostat Minor (¼ in. pipe size) is available either with factory-calibrated fixed orifice or with an adjustable orifice (normally used in series with a Gapmeter).

There is also a special Low Pressure Flostat Minor (non-adjustable volume governor for pressures between 1 and 10 p.s.i.) having particular application to burners where back pressure variations disturb the fuel gas-air ratio. This type is for in-line mounting and has a $\frac{3}{16}$ in. or ¼ in. port and will operate on pressure as low as 1 p.s.i.

Gapmeter direct-indicating variable-area flowmeters are made for pipe sizes; ⅛ in., ¼ in. and ⅜ in. Extension pocket Gapmeters are available for pipe sizes; ½ in., ¾ in. and 1 in. The Flo-scan flow-operated alarm switch can be fitted to any Gapmeter.

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due to the formation of a temporary empty zone; and vice versa. Such undesirable dynamic behaviour can be avoided by controlling the flow of material by the rotational speed of the plate rather than by varying the blade position. For a flow variation of 1.5 or 2. to 1, it is necessary to have a speed range of about 3:1. In a feed unit developed for the Voskresensk Chemical Combine, the hopper is supported on a roller ring so that, as the feeder plate rotates, the hopper follows it due to friction in the material. Six months industrial experience of a plate feeder with rotary hopper shows that reliable continuous supply of materials is obtained, without bridging—a difficulty that has been encountered when using fixed hoppers.

As a result of the Institute's experimental work, plate feeders working in conjunction with hoppers with large outlet openings (600-1,300 mm diameter) and low rotary speeds (0.2-1 rpm) have been adopted.

Flow measurement is carried out by weighing a fixed section of the material conveyor while the material moves at constant speed. For accurate weighing the ratio of the fixed length to the linear speed of movement of the material must be sufficiently high that the weight of the material in the fixed section is not less han 10-15% of the weight of the unloaded conveyor; whereas from the control viewpoint, this ratio should be reduced to a minimum. In the Institute's control unit, this ratio varies between 30 and 150 sec. The conveyor is suspended on rods with the weighing device situated either inside the conveyor or underneath. Accuracy of weight indication is $\pm$ 1 to 1.5%, provided the belt is properly cleaned. A standard proportional-plus-integral controller and electric actuator are used to control the feed speed.

*I. A. Burovoi, Instrument Construction (translated from the Russian), December, 1960, p. 17.

Refrigeration in The Chemical Industry

A SHORT course on Refrigeration in the Chemical Industry will be held in the Department of Chemical Engineering of the Bradford Institute of Technology on Thursday and Friday, 29 and 30 June, 1961.

The fee for the course is £1 10s. 0d.

Further details and application forms may be obtained from the Head of Department of Chemical Engineering, Bradford Institute of Technology, Bradford 7.

Desalinisation Processes

WATER consumption in the United States has risen from 262,000 million gallons per day in 1955 to 312,000 million gallons per day in 1960, and is expected to reach 580,000 million gallons per day by 1980. Although much of this water can in fact be salvaged and recirculated, it seems nevertheless that some areas of the United States will encounter true water shortages unless fresh water sources are supplemented.

For the relief not only of domestic shortages but for arid nations the whole world over, the United States Office of Saline Water is aiming to develop economical desalinisation processes for ocean and brackish waters.* At present, desalted water prices per 1000 gallons mostly lie in the range 1-2.25 dollars, as against 20-40 cents for fresh water. Five different processes at varying stages of development are currently being evaluated.

Due to be operational within the next few weeks is a long-tube vertical multiple effect distillation plant, designed to produce a million gallons a day, at Freeport, Texas. The installation was engineered by W. L. BADGER and associates and the prime contractor is the Chicago Bridge and Iron Company. At San Diego, a million gallon per day multi-stage flash distillation plant, designed and built by Westinghouse, is now under construction. Multi-stage flash distillation is said to be the most efficient process developed as yet, and most recently-built water-desalting plants operate on this principle.

At Webster, SP, a plant for the treatment of brackish water by the electrodialysis method is under construction by the Austin Company of Cleveland under subcontract to Asahi Chemical Industries Company of Tokyo. The capacity is to be 250,000 gallons per day and it is scheduled for operation in the late autumn. At present, the electrodialysis method offers the lowest costs (of the order of 20-60 cents per 1,000 gallons), but is limited to brackish waters.

Also for the treatment of brackish water is a 250,000 gallon per day plant to be constructed at Roswell, NM, operating on the forced-circulation vapour compression system. The contract for this plant has not yet been placed; specifications are being prepared by the Catalytic Construction Company of Philadelphia.

Finally, a 250,000 gallon per day freezing unit is destined for Wrightsville Beach, NC., but as yet the architect-engineer is not selected and contract bidding is at least six months distant. The freezing process is believed by some to promise lower energy costs and less tendency to scaling and corrosion.

**Investor's Reader*, May 10th, 1961, p. 19.

Hydrogen Sulphide Removal by the Stretford Liquid Purification Process

THE Stretford Process, developed jointly by the North Western Gas Board and Clayton Anilline Company, Limited, was intended initially for the removal of hydrogen sulphide from coal gas. Subsequent work in the laboratory and trials at three converted plants has shown that the process is suitable for the removal of H_2S from gas streams of various composition and from solvents immiscible with water.

Many liquid purification systems for the removal of H_2S from coal have been described in the literature and a number are in commercial operation. In the oil and allied industries, such processes as the ethanolamine process, the Seaboard process and the Vacuum carbonate process make use of absorption/desorption of H_2S, the desorbed H_2S usually being fed to a Claus Kiln. Such processes often use corrosive reagents requiring specialised plant.

In the gas industry, the Manchester Process, the Ferrox Process and the Gluud Process rely on the overall oxidation of H_2S to produce sulphur in oxide boxes, and result in high power costs, side reactions and inferior sulphur quality.

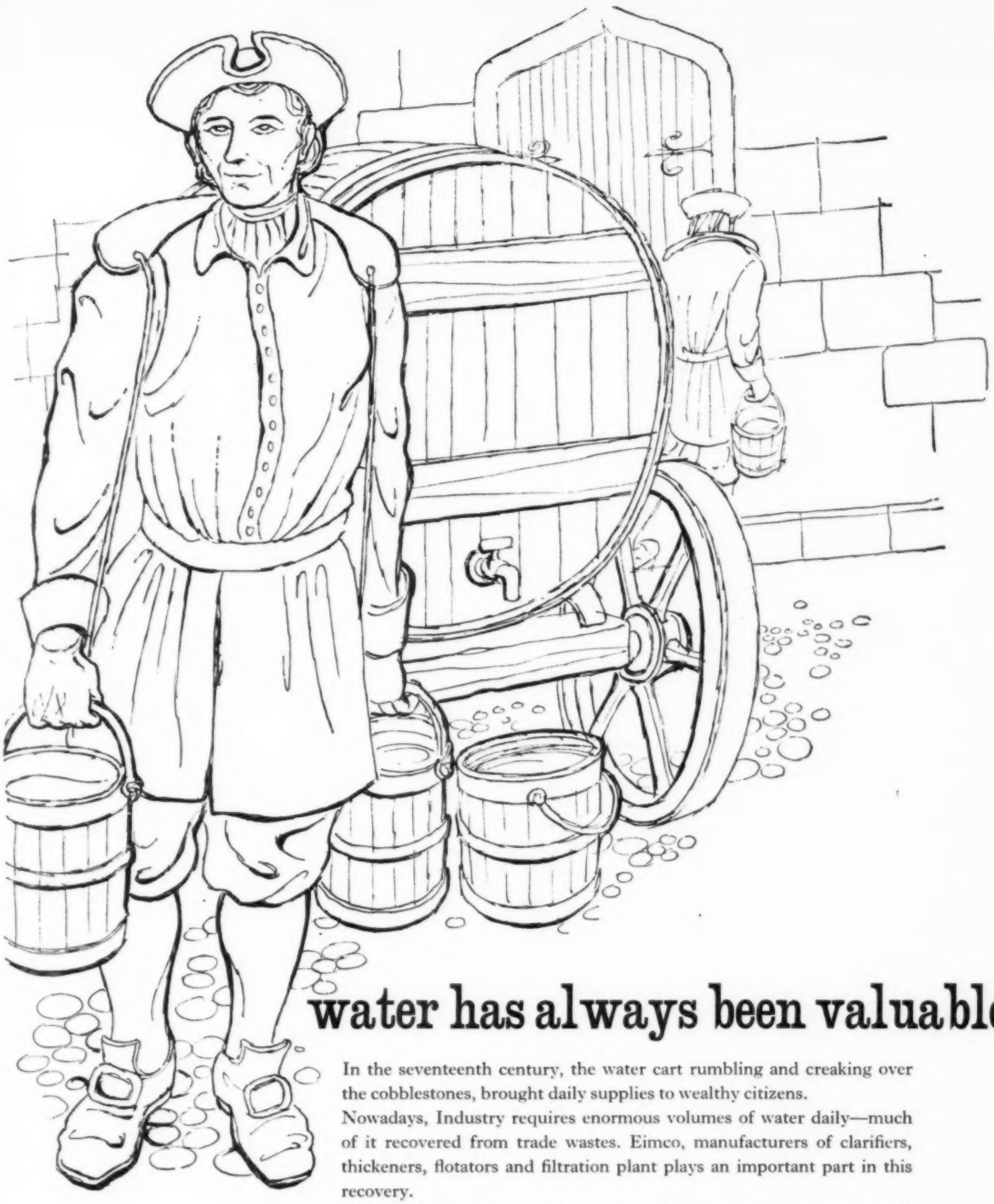
The Stretford Process is a method of continuous purification of gas or liquid mixtures, using an alkaline solution of the sodium salt of anthraquinone 2:6, 2:7, disulphonic acids (ADA) which are water soluble, non-toxic and highly stable under operating conditions. The process, whose overall reaction involves the oxidation of H_2S with atmospheric oxygen:

$$H_2S + \tfrac{1}{2}O_2 \longrightarrow H_2O + S$$

is considered to take place in five stages:

1. Absorption of H_2S in alkali.
2. Reduction of ADA by means of addition of sulphur (in form of hydrosulphide) to a carbonyl group.
3. Liberation of sulphur from the reduced ADA by interaction with oxygen dissolved in the water.
4. Re-oxidation of the reduced ADA.
5. Re-oxygenation of the alkaline solution providing dissolved oxygen in the solution for stage 3 of the process.

These reactions are normally carried out at pH 8.5 to 9.5, which is obtained with sodium carbonate and sodium bicarbonate in the ratio 1:3.



water has always been valuable

In the seventeenth century, the water cart rumbling and creaking over the cobblestones, brought daily supplies to wealthy citizens.

Nowadays, Industry requires enormous volumes of water daily—much of it recovered from trade wastes. Eimco, manufacturers of clarifiers, thickeners, flotators and filtration plant plays an important part in this recovery.

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Compared with oxide boxes, a liquid purification system occupies less space, has a lower capital cost, has a small and steady labour requirement and produces a sulphur that can be converted to a saleable product. Alkaline solutions of ADA are stable, non-corrosive etc. and reduce the H_2S content of a gas to well below the required standard when operation is carried out under the recommended conditions.

An accurate evaluation of this process requires the construction of a plant designed to operate specifically with ADA as reagent. However, from results obtained so far the purification costs are estimated at 0.18d. a therm if the solution is replaced after 24 months and 0.22d. a therm if it is replaced after 12 months.

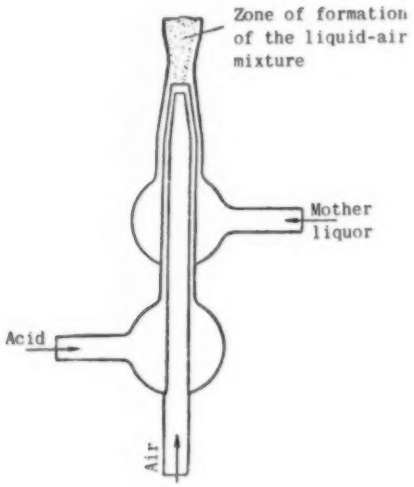
Improvements in the rates of reaction between hydrosulphide and ADA to produce sulphur have been obtained with several additions notably sodium vanadate, and the overall cost of an ADA-vanadate purification process should be below 0.20d. a therm.

*T. Nictin and E. Brunner, paper presented at the 98th Annual General Meeting of the Institution of Gas Engineers in May, 1961.

Continuous Denitration of Sulphuric Acid

IN the U.S.S.R., the Baglei Coke and Chemical Works is accepted as a model-experimental works in connection with complex mechanisation and automation. One of the problems concerned in the automation of the sulphate plant was that of continuous denitration of sulphuric acid.

In the laboratory of UKhIN at the Baglei works, an experimental unit for the continuous denitration of sulphuric acid has been developed.* The main part of this unit is a jet mixer in the form of three concentric tubes terminating in conical nozzles. Air at a pressure of 1.5-1.8 m water gauge is fed via the inner tube; acid enters between the inner tube and the middle tube; and mother liquor from the saturators passes along the outer tube. The mixer nozzle discharges into the bottom of a vertical glass tube about 1,300 mm long with an inside diameter of 9 mm.



At the nozzle outlet, the air jet atomises the acid and mixes it with the mother liquor, so that a large interface develops between the mixture undergoing denitration and the air. The temperature increases considerably as a result of diluting the suphuric acid with mother liquor. The mother liquor brings in ammonium salts which also help to remove the nitric oxide from the mixture. All these factors accelerate the denitration process.

In the laboratory apparatus, the liquid moves up the vertical glass tube as a result of surface friction between the liquid and the gas; the liquid lags behind the gas which promotes considerable agitation at the mixture-air interface. From the top of the tube, the mixture is delivered into a cylindrical receiver, whence the air discharges from the top and the denitrated mixture is collected from the bottom.

In large diameter units, to produce the same conditions of liquid-air interaction, the tube should be fitted with thin-section tubular vertical packing which will enable the surface of the liquid film to develop.

Based on this experimental work, an industrial unit has been designed at the Baglei Coke and Chemical Works to denitrate all the acid supplied to one denitrator. An inside diameter of 70 mm and a working height of 1,500 mm is specified for the denitrating tube. It is intended that the unit should be installed on the acid supply line running from the supply tank to the saturator.

*G. P. Koptev & M. M. Sorkin, Coke & Chemistry, U.S.S.R. No. 11, 1960, p. 37.

Protective Coatings

HOT dipped galvanised-coatings have given good results in studies of the protection of steel tanks in hot water systems, and of structural steel exposed to the atmosphere.* Pilot-scale tanks galvanised in zinc-aluminium baths have remained unpitted for well over a year both in aggressive natural water and in London water from which organic material encouraging the formation of a protective scale had been removed. Conventionally galvanised steel pitted rapidly in both of these tests.

For the protection of structural steel exposed to certain atmospheres, coatings in excess of 3 oz per sq ft are required. Such coatings may be applied by raising the galvanising temperature or by using certain alloy steels for the work, but there are practical objections to both methods. During the past year the British Non-Ferrous Metals Research Association have confirmed that such coatings can be produced on mild steel by prior surface treatment.

BNFMRA have also been investigating protective coatings for aluminium alloys. Sprayed coatings have given protection against corrosion under a wide range of conditions, and they provide valuable protection for high-strength alloys against stress-corrosion under stresses in the short transverse direction.

Research aimed at improving the durability of chromium plating have shown that as the thickness of chromium is increased to 0.000,05 in. or more, there is a progressive improvement in corrosion resistance. There are several types of bath from which thicker chromium can be plated free from cracks, and there is little difference in the corrosion resistance which they impart.

*Annual Report for 1960, British-Non-Ferrous Metals Research Association, p. 22.

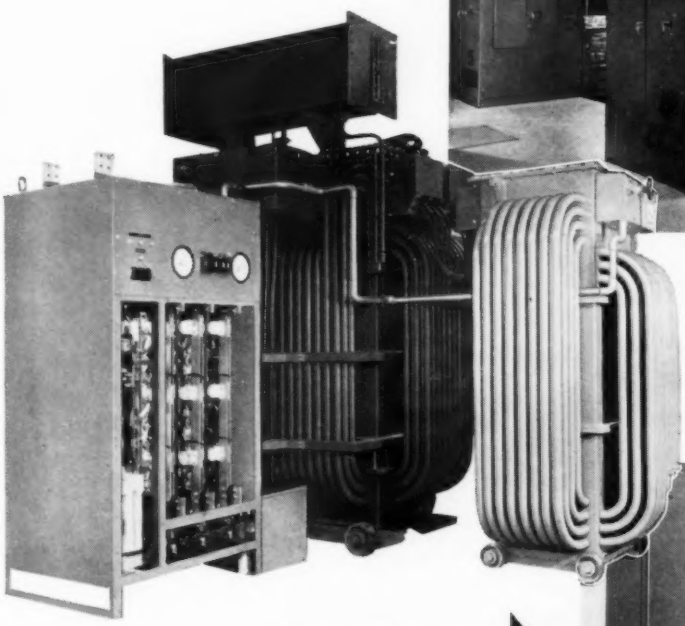
Is Your Pilot Plant Really Necessary

THE view that a fully integrated pilot plant programme should be an exception rather than the rule in process development was expressed by CHARLES R. WIESINGER, of E. I. du Pont de Nemours and Company, at the recent joint meeting of the American Institute of Chemical Engineers and the Chemical Institute of Canada.

RECTIFICATION

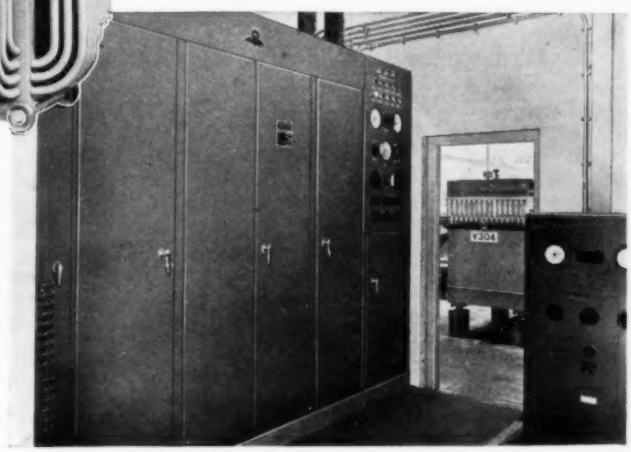
MERCURY ARC

A Mercury Arc Rectifier installation at the works of Western Chemicals Ltd., Alberta, providing an output of 12,000 amps at 510 volts D.C. for electro-chemical duty.



SILICON

A 750 kW 3,000 amp forced air-cooled Silicon rectifier for electrolytic duty in Persia. A voltage regulator is included for voltage variation over the range 180/250 volts D.C.



GERMANIUM

A 6,000 amp water-cooled Germanium rectifier providing a continuous output at 100 volts D.C. for an electrochemical process at the Luton Works of Laporte Industries Ltd.

MERCURY ARC OR SEMI-CONDUCTOR

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Telegrams & Cables: Electric Walton-on-Thames

Alternative techniques include well-devised bench scale tests that can demonstrate yield and conversion; prototype equipment; mathematical analysis; experiments using "pots and pans" to test the effect of recycle, temperature, degradation, fluid flow characteristics, reaction rates, and corrosion and coalescing problems.

Approximately six to eight years might elapse during the development of a new product, of which two to three might be used for pilot plant activities. The incentive to reduce this normal development span is probably around $\frac{1}{4}$ million dollars per month commercial return. Pilot plants are expensive both in initial construction and in operating cost. They are time consuming, not only in construction but also in the analysis of meaningful results. Their existence tends to restrict the exploration of alternatives. In extreme cases, the pilot plant can become a serious bottleneck to the rapid commercialisation of a new product.

On the other hand, pilot plants can reduce the potential of costly mistakes and they can provide small lots. For a polymeric product a pilot plant is almost always necessary for market evaluation. But this is not the case when it is the chemical composition, and not the physical characteristics, of a compound that determines its sales potential.

High Efficiency Mist Scrubber

NEW techniques in the application of special fibre properties for the removal of liquid or solid particles from gases, have led to the development of a filter that efficiently removes sub-micron fume particles at a moderate pressure loss.

This type of gas fume filter has been described earlier[1]; several of them have now been manufactured[2] and they compare very favourably with other forms of gas filtration equipment.

The filter medium is terylene fibre on which particles are collected as discrete particles not in a continuous film. The unit is therefore self-draining and operates at a constant pressure drop. The expected life of the filter varies from 1-2 years depending upon the application. Terylene is attacked by alkalis but not by mineral acids except at high concentration and temperature conditions. This is in contrast to the "throw away" fibre filters characterised by gradual increase in pressure drop.

The particles generally removed by these new mist scrubbers are 0.5 to 2.0 microns in size and a minimum scrubbing efficiency of 95% is usually obtained. The following performance data are reported[2] (a) Sulphuric acid mist treatment with SO_3 removal efficiency of 98.6% and a steady pressure drop of 7 in w.g. maintained over 18 months, (6) Sulphuric acid mist treatment with efficiency of 99.6% (outlet conc. 0.00036 grains SO_3/cu ft and pressure drop 9 in w.g. (c) Sodium oxide smoke filtration with 99% estimated efficiency and 18 in w.g. (d) Organic acid fume filtration with 86% efficiency and 10 in w.g.

Pilot plant work is being successfully carried out on ammonium chloride fumes and all previously untried fumes are treated on a pilot plant before the specific unit is designed.

1. G. L. Fairs Trans. Inst Ch. E. 1958 36 475-85.
2. Nordac Ltd., Uxbridge, Middlesex.

Treatment of Polluting Liquids

PROMISING results have been obtained in experiments at the Water Pollution Research Laboratory on the aeration of water by means of a Venturi aerator.* In this investigation, water from an 1100 gallon tank, 13 ft deep, was recirculated through the Venturi, so arranged that the mixture of water and induced air was discharged directly from the Venturi into the tank.

For tap water initially completely devoid of oxygen, an increase in the dissolved oxygen concentration of from 3-6 ppm could be obtained, depending on the conditions. Additions of synthetic anionic detergents in solution increased both the oxygen increment and the aeration efficiency, the energy consumption being unaffected. This effect is in contrast to that found with diffusion-air systems, probably due to the shearing of the induced air into very much smaller bubbles than are obtained in detergent-free tap water.

It appears that a much better performance is obtained when the Venturi is placed at the submerged end of a discharge pipe rather than in the pipe itself. If full-scale performance matches that obtained in the laboratory, it would appear that this method of aeration would be comparatively simple and economical for discharges which are normally pumped into the receiving water.

Another subject under study at the Water Pollution Research Laboratory is the biological treatment of coke oven effluents. Experiments have been carried out with pure cultures of thiobacillus thiocyanoxidans with a view to determining its generation time, the organisms being grown in a number of reactors operated on the continuous flow principle. Oxygenation and mixing were obtained by coarse-bubble aeration. The concentration of thiocyanate in the reactor, as compared with the concentration of the influent, indicated a generation time in excess of 40 hours under the test conditions. Addition of vermiculite and pumice was found to increase the rate of thiocyanate removal.

The percolating filter is particularly suitable for the growth of an organism which grows well as a surface film. Although in a stirred reactor it has not been possible to remove thiocyanate from an influent containing untreated coke oven liquor, in the percolating filter it is possible to destroy both phenol and thiocyanate. One filter treating a 20 per cent solution of coke oven liquor in tap water (550 ppm phenol, 100 ppm CNS) at 60 gal/cu. yard day removed all but a trace of the phenol and all the thiocyanate. The permanganate value was reduced from 1350 to 80 ppm in the settled effluent which also contained nitrate equivalent to 11 ppm N.

DIARY

International Congress of Pure and Applied Chemistry

August 6-12. 18th Congress, Queen Elizabeth Hotel, Montreal, Canada.

Chemical Institute of Canada

August 3-5. 44th Canadian Chemical Conference and Exhibition, Queen Elizabeth Hotel, Montreal, Canada.

British Conference on Automation and Computation

June 27-30. Harrogate. The conference entitled "Automation—Men and Money." Further information from MRS. HODSON, Conference Secretary, British Institute of Management, 80 Fetter Lane, London, E.C.4.

British Association for the Advancement of Science

August 30-September 6. St. Andrew's Hall, Norwich, Annual Meeting.

American Society of Mechanical Engineers and Others

August 28-September 1. International Heat Transfer Conference, Boulder, Colorado, U.S.A.

Registration information and advance programmes may be obtained from the A.S.M.E., Meetings Dept., 29 West 39th Street, New York 18, N.Y., U.S.A.

HEAT TO ELECTRICITY VIA THERMIONIC GENERATOR

SINCE the 1920s it has been known in principle that the thermionic diode provides a means for the direct conversion of heat to electricity. It has an electron emitter which accepts heat and delivers electrons across an intervening space to a collector electrode. The efficiency is limited by the negative space charge produced by the cloud of electrons in the vicinity of the cathode. If this space charge can be neutralised, it is possible to increase the flow of current to a useful level.

A practical way of achieving this is now under development by PROFESSOR D. GABOR, F.R.S., of the Imperial College of Science and Technology, sponsored by the National Research and Development Council, in which argon or an argon-mercury mixture is used as an ion source for space-charge neutralisation.

In PROFESSOR GABOR'S diode the main discharge occurs between a heated emitter and a collector electrode, the latter of cellular construction in order to produce a large collector area compared with that of the emitter. The voltage drop in the main discharge space is a fraction of a volt so that no ionisation takes place in this region, which appears dark. Positive ions are injected into this space from an auxiliary discharge between a gauze electrode and an auxiliary anode. In operation a small fraction of the electric current is ejected from the dark plasma in the form of fine electron beamlets through the gauze where an acceleration region develops with a drop just sufficient for ionisation to take place. A large fraction of the ions formed in this way return through the gauze into the main discharge space.

The cellular collector electrode is made of a metal of high heat conductance, the cellular structure being interspersed with metal bars which conduct the heat away to a cooler. The cell dimensions would be about 3-5 mm. and they would be located about 1 mm. away from the emitter face. This arrangement is suitable for producing current densities of about 4 amp. per square centimetre; smaller dimensions would be needed for higher current densities. A metal gauze fixed to the top of the cellular structure separates main and auxiliary discharge spaces. A single discharge space is preferable to one broken up into smaller units since it ensures that the discharge will spread over the whole surface of the gauze.

The emitter area is divided into hexagonal units, each provided with its own cathode lead. In this way the tendency of the magnetic field associated with the electric current to reduce electron emission is minimised.

Operating at emitter temperatures in the range 1,500 to 1,800°C. efficiencies of the order of 20 to 30 per cent and power densities of the order of 4 to 6 kilowatts per square foot should be achieved.

The Gabor thermionic generator can be used for AC generation as well as for direct current, but with a somewhat lower efficiency—estimated at about 22 per cent as against 30 per cent for DC. This drop might well be outweighed by the reduction in cost of the plant compared with conventional alternators.

Now proved in principle, further research is still required to develop materials for the cathode, the collector electrode, and a ceramic envelope capable of operation for long periods at 1,800°C. and with high thermal shock resistance.

*N.R.D.C. Bulletin, April 1961, p. 8.

PROFESSIONAL APPOINTMENTS

Warren Spring Laboratory, (D.S.I.R.), Gunnels Wood Road, Stevenage, Herts., requires Scientific Officer/Senior S.O. Chemist, in Hydrometallurgy Group investigating new methods of extracting metals from ores or industrial wastes by leaching, ion exchange, liquid-liquid extraction and chlorination. Work includes basic and applied research on laboratory and pilot scale. Applicants should be interested in basic research in these fields and in the application of this research to practical problems. Sound knowledge of solution chemistry required. Research experience desirable but not essential. Quals:- 1st or 2nd Class Hons. degree or equivalent in chemistry or extraction metallurgy. Successful applicant will be encouraged to publish and maintain contact with other workers and to take full part in proceedings of learned Societies. Opportunities for travel. Interim salary ranges:- S.O. £717-£1,186. S.S.O. £1,302-£1,604. For S.S.O., at least 3 years post-graduate experience required, and at least age 26.

Application form and further information from the Director, address as above, quoting W.S.L.9Z. Closing date 29th July, 1961.

Vacancies exist for

QUALIFIED CHEMISTS

at the Board's Central Laboratories at Old Kent Road, S.E.15, and at the Tar Works, Tunnel Avenue, Greenwich, S.E.10, to work on problems associated with the use of tar products in various industries. Some industrial experience is desirable and an interest in chemical engineering would be an advantage. Starting salaries would normally be in the range £800-£955 per annum, but a higher salary would be considered in view of special experience or qualifications.

Applications in writing, giving full details and quoting reference V137/1478, should be sent to the Personnel Manager, SOUTH EASTERN GAS BOARD, Katharine Street, Croydon, within seven days.

COALITE AND CHEMICAL PRODUCTS LIMITED have vacancies in their laboratories at Bolsover for chemists and technologists who would be interested in work related to the low temperature carbonisation of coal. The work is both interesting and rewarding. For those possessing outstanding capabilities, opportunities will arise for employment in, or transfer to research work and to production supervision.

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Applications stating age, experience, qualifications and salary required to:—

Assistant Managing Director,
Coalite and Chemical Products Limited,
P.O. Box No. 21
Chesterfield.

In addition to filling these particular vacancies, applications are invited from young men aged 17/20 years, interested in science, with a view to training in the carbonisation and coal chemicals industry.

SENIOR CHEMICAL ENGINEERS

A medium sized contracting organisation located in central Manchester requires Senior Chemical Engineers capable of negotiating at all levels for its own design and technical service staffs. The applicants should have a degree or equivalent in Chemical Engineering or allied sciences and have at least 10 years varied experience in the chemical or petroleum industry. A broad field is required for the technical service engineers and some design experience for those in the design department. The salaries offered are commensurate with the best in the United Kingdom. Applicants should write to the Manager, Process Plant Contractors (Campbell) Limited, 89, Oxford Street, Manchester, 1.

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Further particulars and forms of application may be obtained from the Registrar, Bradford Institute of Technology, Bradford, 7. (Department A.11).

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Clerk to the Governors.

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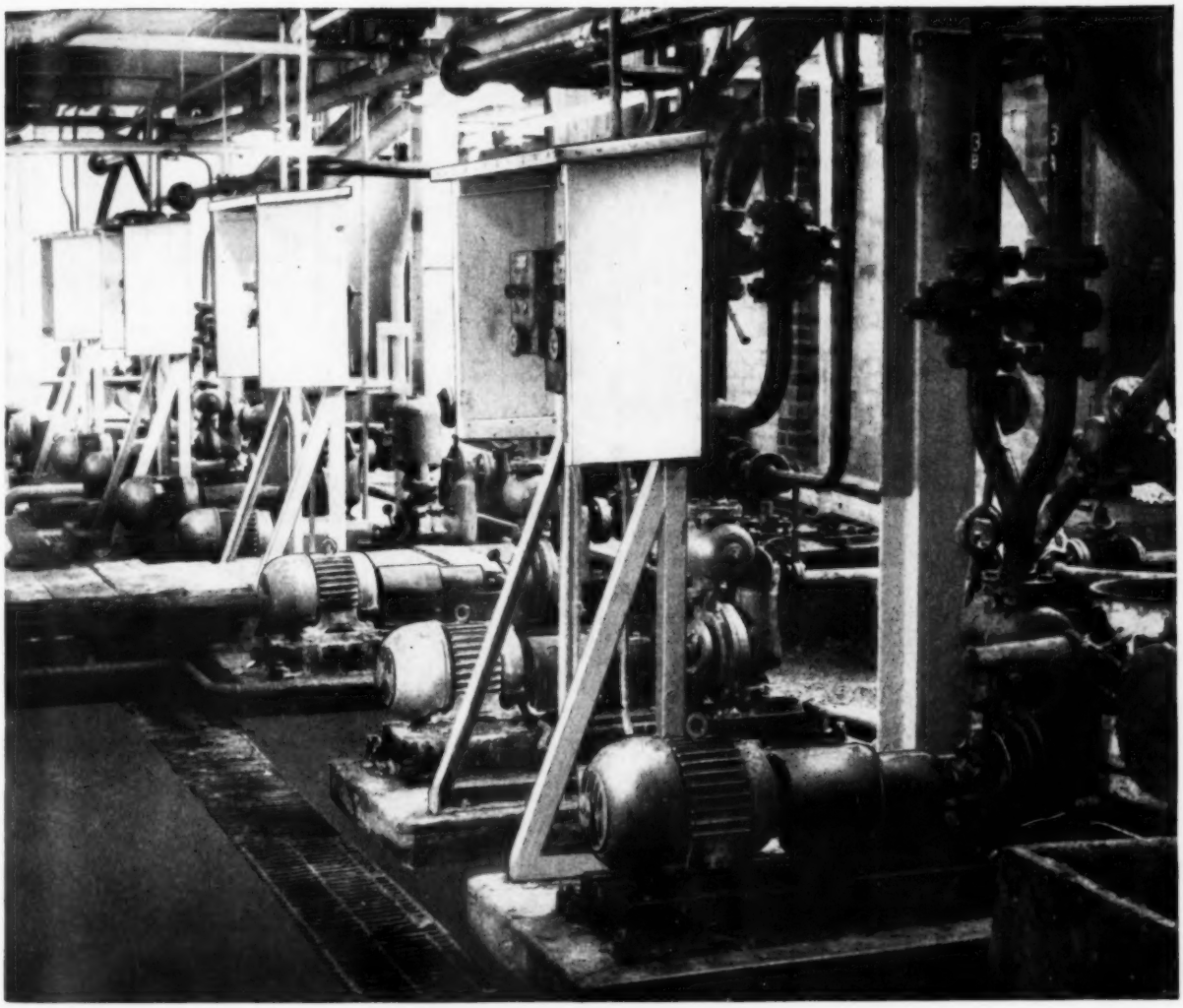

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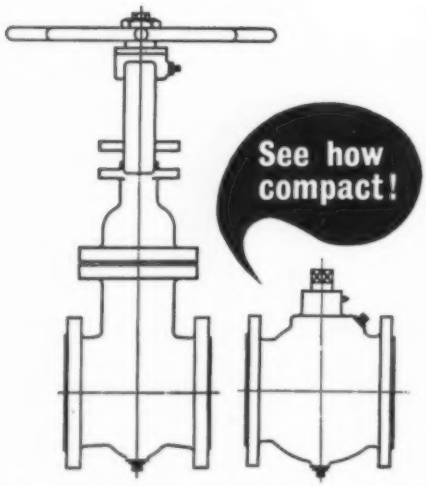

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A HEYWOOD PUBLICATION
British Chemical Engineering

Reflections on a Fair

FROM all unbiased accounts, the British Trade Fair in Moscow, organized by a company closely associated with the proprietors of this journal, and which closed last month, has undoubtedly been an outstanding success; and although it is perhaps premature to attempt to assess the commercial value of this venture, such indications as the sale of over 90 per cent of the goods displayed, the interest displayed by official Soviet commercial organizations and by parallel organizations from other planned-economy countries, the substantial contracts already concluded—the £4-million order for a nylon factory secured by Vickers is a case in point—justify an optimistic view of the outcome. Bearing upon this is the immense interest in the various exhibits shown by ordinary Russian citizens, a factor which should by no means be overlooked, because this interest can provide an important rank-and-file influence upon those Russians who have authority to make purchases. And one quite clear benefit arising from the Fair is that a door has been opened, clearly shown by the invitation to its organizers to hold a similar exposition in Budapest with the emphasis upon chemical plant and textile machinery.

It is in many ways opportune that the Fair, with its indications of a huge potential market, should have taken place at a time when the problem of the Common Market is before us. If one breaks away from the fixation which afflicts so many authorities on trade, particularly those whose opinions so frequently grace the national daily Press, and reviews the recent history of restrictive trade groupings, one cannot help but conclude that they lead to all kinds of complications, do not improve the international climate, while the discriminatory measures they adopt in the long run prove to be futile. So far as the Common Market is concerned, it is interesting to see how much shifting of ground has taken place on this topic. Once upon a time the prevalent view was on no account should Britain join, whereas today it is being suggested that we should join unconditionally, assuming that this would be allowed.

Of course, it would be useless to ignore the difficulties facing those who have to decide the issue; their dilemma arises from the pattern of British exports which are increasing to America and Europe, but declining to the Commonwealth. The still huge market with the Commonwealth countries is maintained in part by the system of preferences whereby goods from the Commonwealth countries enter Britain duty free or at reduced tariffs. If, as membership of the Common Market would require, a standard tariff were imposed upon goods from the Commonwealth, it would be impossible for them to compete with goods coming into Britain from Europe. This would almost certainly mean that the value of British goods purchased by Commonwealth countries would drop, with resulting serious consequences for the British economy. The magnitude of the danger can be appraised from the fact that, despite the trend, some 50 per cent of this country's exports go to the Commonwealth and Canada. Then, in addition to the obvious risk, the suspicion that Britain's economic policy would be determined by other powers is by no means groundless.

What seems so short sighted is to present the alternative to the Common Market, with its admittedly gloomy prospects of any secure benefits to Britain, as abstention accompanied by serious loss of trade. The possibility of another alternative—the extending of Britain's trading area to all countries of the world—seems to have eluded consideration, and one of the things the Moscow Fair has done has been to underline this alternative.

As things in this respect stand at present, a relatively small amount of trade is carried out with the planned-economy countries—amounting to about 2 per cent of Britain's exports in 1960. But judged alongside the 1,000 million population of these countries and the 600 million of the Commonwealth, the misalignment of Britain's export pattern is clear enough; in the circumstances, just as individual companies find it necessary to diversify their activities, a major commercial nation should diversify both geographically and in the pattern of its export trade.

It is worth reminding ourselves, in considering the whole question of trade, that Britain's position as a trader has been a steadily declining one over a number of years. As an example, during the past decade our share of the world market has fallen from a little more than 25 per cent to 17 per cent, while that of West Germany has risen from 15 per cent in 1954 to over 19 per cent by 1960.

The many obstacles which have been placed in the way of East-West trade from time to time have been accompanied by a variety of arguments; the two most significant hinging around the strengthening-a-potential-enemy angle and the presumed unreliability of the Eastern grouping as a market. The first argument has been adequately disposed of on many occasions, but the second deserves more serious consideration, especially since some manufacturers who were present in Moscow recently expressed fears of this kind. The smaller manufacturer may feel that a large order, tying up virtually his entire productive capacity for a year or more, may result in the loss of markets elsewhere if future orders from the East are not obtained and if his product is copied by the purchaser. However real this risk may be, this is surely a subject for frank discussion between prospective seller and buyer. Looked at more closely, the argument of unreliability is scarcely justified, since the economies of the Eastern grouping of countries are stable, and are expanding at the rate of more than 10 per cent annually. Moreover, the types of goods these countries require happen to be just those which Britain, with its specialized manufacturing facilities, is able to supply.

There is, of course, the problem of what should be bought in exchange, and while it is customary to look upon that area of the world as a supplier of raw materials, it should be remembered that these countries, too, have engineering goods to offer and already there are a number of examples of Russian machinery which is acquitting itself successfully in the hands of British engineering firms. It may well be, however, that a better idea of what can be offered in exchange for our capital and consumer goods will be provided by this month's Exhibition at Earls Court.

539.214:539.5:66.063.7

DESIGN WITH NON-NEWTONIAN FLUIDS

Methods for design of equipment to handle non-Newtonian fluids are given in a form which permits their rapid use in practical problems. Calculations of power input to stirred vessels and pressure drop through pipes are considered with worked examples

by J. W. RICHARDS

WHILE fluid calculations involving Newtonian fluids are covered thoroughly by standard chemical engineering texts, there are relatively few practical methods for calculations involving non-Newtonian fluids, and those which exist are scattered throughout the literature. Furthermore, the study of rheology has a very small place in the majority of training courses for chemists and chemical engineers.

In spite of this, the practising chemical engineer frequently faces problems involving liquids having anomalous rheological properties. Materials like rubber solutions, starch suspensions, mayonnaise, paper pulp slurries and some fermenter mashes are pseudo-plastic; coal, rock and chalk slurries, sewage sludge and some chocolate mixtures are Bingham plastic; some greases and paints are thixotropic, and so on. A useful list of such materials is given by CALDERBANK and MOO-YOUNG.[1]

The purpose of this paper is to present in a form for use in practical calculations some of the published methods which the author has found most useful. The paper departs from usual practice in that no attempt has been made to use either the c.g.s. system or the ft lb sec system of units consistently. This is because rheological properties are normally measured and quoted in c.g.s. units, while pressure drops, pipe diameters, etc., are most useful to the British chemical engineer in ft lb sec units. However, all equations given in the paper are dimensionally consistent, and contain the appropriate unit conversion factors where necessary, for use with the units given in the list of symbols at the end.

1. Rheological Types

For rheological purposes, fluids may be divided into three main types. These main classes and their principal subdivisions are defined below. Such definition of terms is necessary, because in the literature a number of different names are sometimes used to describe the same phenomenon.

MR. RICHARDS is manager of the Fermentation Group of Cyanamid of Great Britain Ltd., at Gosport. Previously he studied at Southampton University, and has held positions with British Geon Ltd. and Glaxo Laboratories Ltd.

1.1. Newtonian Liquids

In the case of Newtonian liquids, the shear stress (τ) is directly proportional to the rate of shear (γ), and the viscosity (τ/γ) is independent of shear rate. Fig. 1 shows a plot of shear stress against shear rate for a Newtonian liquid. The viscosity is given as the slope of the line and can be obtained from one measurement with a viscometer.

1.2. Time-independent Non-Newtonian Fluids

(*a*) *Bingham Plastics.* A plot of shear stress against shear rate for a Bingham plastic gives a straight line with an intercept on the shear stress axis. This intercept (τ_y) is the yield stress of the fluid, and the slope of the line is called the coefficient of rigidity.

(*b*) *Pseudoplastic Fluids.* A pseudoplastic fluid is one whose apparent viscosity decreases instantaneously with increasing rate of shear. A plot of shear stress against shear rate starts at the origin (cf. Bingham plastic) and shows a very slow increase in flow rate (shear rate) with moderately low shear stresses. The curve becomes a straight line at high shear rates. The slope of the straight portion is called the plastic viscosity (μ_p).

(*c*) *Dilatant Fluids.* Dilatancy can be considered as the opposite of pseudoplasticity. It is sometimes called inverted plasticity. The apparent viscosity of a dilatant fluid increases instantaneously with increasing rate of shear.

1.3. Time-dependent Non-Newtonian Fluids

(*a*) *Thixotropic Fluids.* A thixotropic suspension can be considered as possessing a structure, the breakdown of which is a function of time as well as of the rate of shear. The structure can rebuild itself when the shearing force is reduced. The apparent viscosity of a thixotropic fluid decreases with time to some minimum value at any constant rate of shear.

A plot of shear stress against shear rate using points obtained by changing the shear rate at regular time intervals

shows a definite hysteresis effect; that is, a different curve is obtained for increasing and decreasing shear rates.

At constant shear rate, a plot of shear stress against time shows that shear stress decreases with time to a minimum value.

(*b*) *Rheopectic Fluids.* Rheopexy may be considered to be the opposite of thixotropy; that is, a rheopectic fluid is one whose apparent viscosity increases with time to some *maximum* value at any constant rate of shear. The phenomenon is relatively rare.

2. Power Requirements of Stirred Vessels

2.1. Newtonian Fluids

In the case of Newtonian fluids, estimation of power requirements and scale-up of equipment is relatively straightforward. RUSHTON, COSTICH and EVERETT[2, 3] give the basic equations required for scale-up, while for estimation of power consumption other papers by OLNEY and CARLSON,[4] and WHITE and SUMERFORD[5] are also useful.

For the general case for geometrically similar vessels, RUSHTON gives

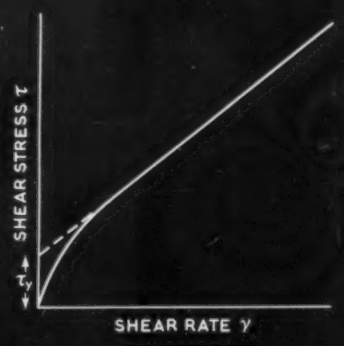
$$\frac{Pg}{\rho N^3 D^5} = K\left(\frac{D^2 N\rho}{\mu}\right)^x \times \left(\frac{DN^2}{g}\right)^y$$

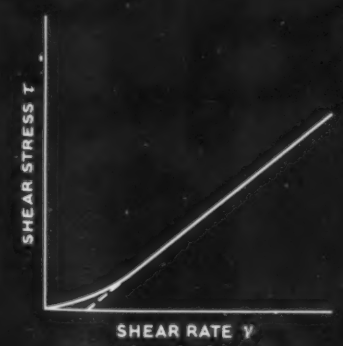
where K, x and y are constants for the system.

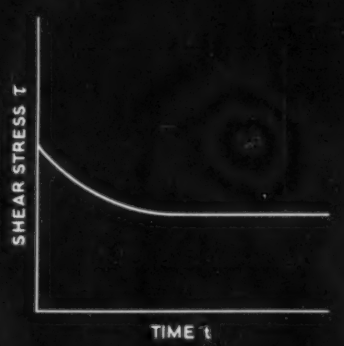
The exponent y of the Froude number (DN^2/g) is zero

Symbols Used

D = impeller or pipe diameter (ft);
D_i = overall diameter of impeller (ft);
D_t = internal diameter of vessel (ft);
f = Fanning friction factor;
F = friction head (ft lb force/lb mass of fluid);
g = gravitational conversion factor (32.17 lb mass × ft lb force × sec^2);
L = length of pipe (ft);
N = rotational speed (rev/sec);
N_{Re} = Reynolds number (dimensionless);
P = power (hp);
Pl = Plasticity number (dimensionless);
t = time (sec);
T = temperature (°C);
u = mean fluid velocity (ft/sec);
γ = shear rate (sec^{-1});
$\triangle P$ = pressure drop (lb/ft^2);
η = coefficient of rigidity (centipoises);
μ = viscosity (centipoises);
μ_a = apparent viscosity (centipoises);
μ_E = effective viscosity (centipoises);
$\mu_{e.u.}$ = viscosity (English units = centipoises/1488);
μ_p = plastic viscosity (centipoises);
ρ = fluid density (lb/ft^3);
τ = shear stress (dyne/cm^2);
τ_y = yield stress (dyne/cm^2).







unless a vortex is formed, and under these conditions scale-up from pilot plant to full size is not possible unless different liquids of suitable viscosity and density are used in the two sizes of vessel.

For fully baffled vessels, the expression simplifies to

$$P = \frac{k}{g} \cdot \rho N^3 D^5 \cdot \left(\frac{D^2 N \rho}{\mu}\right)^x$$

If the Reynolds number ($D^2N\rho/\mu$) of the impeller is below about 10, the exponent $x = -1$ and the equation reduces to

$$P = \frac{k}{g} \cdot \mu N^2 D^3 \text{ for viscous flow.}$$

If the Reynolds number is above 1000, $x = 0$, and

$$P = \frac{k}{g} \cdot \rho N^3 D^5 \text{ for turbulent flow.}$$

Thus for viscous flow the power input is directly proportional to the viscosity and independent of the density of the fluid. For turbulent flow, the power is directly proportional to the fluid density and independent of the viscosity. In between $N_{Re} = 10$ and 1000, x can vary from -1 to 0, and this region should be avoided, whenever possible, in impeller design.

For Newtonian liquids in viscous flow, the viscosity as determined by a single point measurement with a viscometer can be used in the above equation. Newtonian liquids have only one value of viscosity at a given temperature, irrespective of stirrer speed.

2.2. Non-Newtonian Fluids

In the case of non-Newtonian fluids, the same basic equations apply as for Newtonian fluids. However, the value of the viscosity used to calculate the Reynolds number must be the value measured at the appropriate shear rate for the impeller. It is necessary always to determine the Reynolds number in order to ascertain whether viscous or turbulent conditions obtain in the vicinity of the impeller.

In working with non-Newtonian fluids a rotational viscometer such as the Brookfield or Ferranti must be used, as it is necessary to know the steady shear rate at which each measurement is made. For power input calculations for non-Newtonian fluids, the following procedure is suggested.

Using data obtained with the viscometer, a graph is prepared of shear stress against shear rate, and one of apparent viscosity (μ_a) against shear rate. Also, the change (if any) in shear stress at constant shear rate is plotted against time. These graphs yield all of the essential data and permit classification of the fluid into one of the above rheological types.

To translate spindle speed N (revs/sec) into shear rate for the viscometer, shear stress is plotted against spindle speed, on log-log co-ordinates. A straight line is obtained, of slope n, where

$$\tau = \text{Constant} \times N^n$$

It is not necessary for this purpose to calculate the actual shear stress, and the direct viscometer scale reading may be used instead.

The shear rate corresponding to any spindle speed is then obtained from the expression[1]

$$\gamma = \frac{4\pi N}{n}$$

CALDERBANK and MOO-YOUNG[1] give equations for calculating the rate of shear produced by the impeller of a stirred vessel as follows:

$\gamma = 10N$ for Bingham and pseudoplastic fluids,

and $\gamma = 12.8N\left(\frac{D_i}{D_t}\right)^{0.5}$ for dilatant fluids.

Here, D_i is the overall diameter of the impeller and D_t is the internal diameter of the vessel.

Having determined the shear rate in the main vessel for a given impeller speed, the appropriate value of apparent viscosity can be read from a graph of apparent viscosity against shear rate obtained with the viscometer. This value of the apparent viscosity is used to calculate the Reynolds number, and, if the Reynolds number obtained is below 10, is used in the power equation

$$P = \frac{k}{g} \cdot \mu \times N^2 D^3$$

If N_{Re} is above 1000, no further use is made of the viscosity, and the power input is obtained from

$$P = \frac{k}{g} \cdot \rho \times N^3 D^5$$

Normally, in the case of Bingham plastic, pseudoplastic and thixotropic fluids, the starting torque of the stirrer motor will be higher than would be the case with a Newtonian fluid. However, apart from exceptional fluids, or cases where a large amount of starting and stopping is required, the normal damping of the overload trips is enough to permit stirring to start, after which the load falls rapidly at higher rates of shear.

Dilatancy will give no trouble on starting, as the apparent viscosity at the working shear rate is higher than at initial rates of shear.

Example 1

Mashes of moulds and actinomycetes are frequently encountered in antibiotic production and are generally non-Newtonian.[6] The data used in the following example were obtained from mash from an antibiotic fermentation, using a Brookfield LVT viscometer.

Spindle speed (revs/sec) (N)	0.05	0.1	0.2	0.5	1.0
Scale reading (α shear stress)	5.5	8.75	10.8	13.7	16.8
Apparent viscosity (centipoises)	550	437.5	270	137	84

From a plot on log-log co-ordinates of scale reading against spindle speed, the slope of the straight line obtained is 0.275 (n).

Then shear rate $= \gamma = \frac{4\pi N}{n} = 45.8N$

This permits translation of spindle speed to shear rate (γ sec^{-1}) as tabulated below.

Shear rate (γ sec^{-1})	2.29	4.58	9.2	22.9	45.8
Apparent viscosity (μa centipoise)	550	437.5	270	137	84

These data were plotted on linear co-ordinates to give the apparent viscosity at any rate of shear, and the slope of the curve showed that the fluid was pseudoplastic. A further test, that of measuring the shear stress (scale reading) over a period of 10 min at a constant spindle speed, showed a very slight tendency for the reading to fall. This indicated that the mash was slightly thixotropic (see Fig. 6).

Suppose, for the sake of convenient figures, that we wish to calculate the power input required for an impeller of 1 ft diameter to run at 137.5 revs/min in the mash.

Then shear rate $= \gamma = 10N = 22.9$ sec^{-1}.

From the table above (normally the graph of the data) the apparent viscosity at a shear rate of 22.9 sec^{-1} is 137 centipoises. The impeller Reynolds number is then given by

$$N_{Re} = \frac{D^2 N \rho}{\mu_a} \times 1488 \simeq 1550$$

The specific gravity of the mash is here taken as 1.0.

Turbulent flow conditions therefore obtain, and the calculation of the power requirement from

$$P = \frac{k}{g}\rho N^3 D^5$$

does not require the inclusion of the viscosity. Had the value of N_{Re} come to be less than 10, the apparent viscosity would have been used in the expression

$$P = \frac{k}{g}\mu_a N^2 D^3$$

3. Pressure Drop in Pipes

Newtonian Fluids

For Newtonian fluids, calculation of pressure drop in pipes is a relatively simple matter. If the fluid concerned is known to be Newtonian, only a single determination of viscosity with the viscometer at the appropriate temperature is required. The pressure drop is then calculated either from one of the standard friction factor-Reynolds number plots or from the expressions:

$$\Delta P = \frac{32L \cdot u \cdot \mu_{e.u.}}{gD^2} \qquad \text{for viscous flow}$$

or

$$\frac{\Delta P D}{u^2 L \rho} = 0.0001906 + \frac{0.01171}{N_{Re}^{0.38}} \qquad \text{for turbulent flow (through new mild steel pipe)}$$

Non-Newtonian Fluids

(*a*) *Viscous Flow*. For viscous flow of a Bingham plastic, the effective viscosity of the fluid is given by SCOTT BLAIR[7] as

$$\mu_E^* = \frac{g_c \tau_y^* D}{6u} + \eta^* \qquad (* \text{ ft lb sec units})$$

Converting μ_E, τ_y and η to the units given in the table at the end of this paper, the equation becomes, for practical use:

$$\mu_E = \frac{16.67\ \tau_y\ D}{u} + \eta$$

The values of the yield stress (τ_y) and the rigidity coefficient (η) may be determined using a rotational viscometer. To do so, the scale reading is plotted against the spindle speed, and two points are selected on the straight portion of the curve (see Fig. 2). Suppose that these points are at 30 and 60 revs/min. Then, using the apparent viscosity at these speeds, the yield stress and rigidity coefficient are given by[8, 9]

$$\tau = 0.6(\mu_{a30} - \mu_{a60}) \text{ dynes/cm}^2$$
$$\eta = 2\mu_{a60} - \mu_{a30} \text{ centipoises}$$

This applies also in the case of a pseudoplastic fluid. The values of τ_y and η are used as above to calculate μ_E, which is then used in the expression

$$\Delta P = \frac{32\ L\ u\ \mu_E}{g\ D^2}$$

Where μ_E is in English units (centipoise/1488). The expression given by PERRY[10] differs from this by the fact that PERRY'S units for yield stress are lb force/ft^2 instead of dynes/cm^2.

For dilatant fluids, the value of the yield stress would be negative. In pressure drop calculations, therefore, the worst condition is assumed for safety and η is used direct instead of μ_E. Thixotropy may be ignored, and thixotropic fluids are treated as for Bingham plastic and pseudoplastic fluids, bearing in mind that calculated pressure drops will then be a little higher than actual, depending on the degree of thixotropy.

In the case of rheopectic fluids the viscometer must be used to determine limiting values of apparent viscosity for the τ_y and η calculations. This means that the spindle must be allowed to revolve for several minutes at each spindle speed, until the reading rises to a steady value. Conversely for thixotropic liquids, the initial scale reading after only two or three revolutions is preferable for safety in pressure drop calculations. These conditions of measurement for thixotropic and rheopectic fluids apply whether the fluid is to be in viscous or turbulent flow.

The above method is quite suitable for non-Newtonian fluids where the yield stress is fairly low. In cases of high yield stress and where greater accuracy is required, the method of WELTMANN[11] is probably better.

By this method, the Fanning friction factor (f) for use in the pressure drop equations of the type:

$$F = \frac{4fLu^2}{2gD}$$

is obtained either from an equation or a diagram. For pseudoplastic and dilatant materials

$$f = \frac{4}{N_{Re}}\left(\frac{3n+1}{n}\right)$$

where n is the slope of the τ-γ plot mentioned earlier. The value of viscosity for use in determining this Reynolds number is the apparent viscosity at the shear rate obtaining in the pipe. The rate of shear in the pipe is given approximately by

$$\gamma = \frac{2u\left(\frac{1}{n}+3\right)}{D} \text{ sec}^{-1}$$

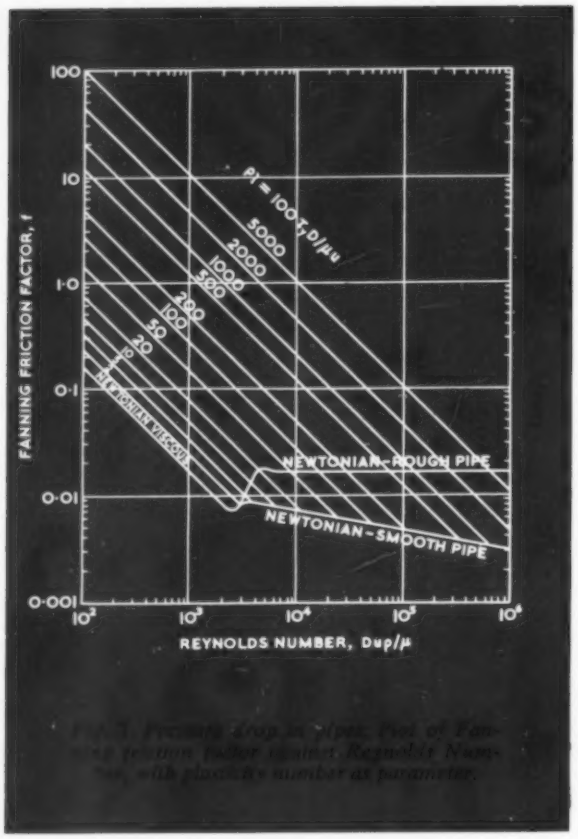
For Bingham plastic materials Fig. 7 is used. WELTMANN'S original diagram has been re-drawn in terms of Fanning friction factors as these are more commonly used in this country. The value of the Reynolds number for use in Fig. 7 should be calculated using η, the rigidity coefficient, for the viscosity term. The plot gives Fanning friction factor against Reynolds number, with the Plasticity number $Pl = 100\ \tau_y D/u\eta$ as parameter.

(*b*) *Turbulent Flow*. In order to determine whether a non-Newtonian fluid in a pipe will be in viscous or turbulent flow, the same criterion is applied as for Newtonian fluids. Thus, using the value for μ_E as calculated above, the Reynolds number is calculated. N_{Re} below 2100 indicates streamline flow, when N_{Re} above 4000 indicates turbulent flow. As usual, pipe design to give Reynolds numbers in the range 2100 to 4000 should be avoided.

For turbulent flow of Bingham plastic, pseudoplastic, dilatant, thixotropic or rheopectic fluids, the coefficient of rigidity or plastic viscosity should be used for calculations of Reynolds numbers to be used in pressure drop calculations.[12] The term rigidity coefficient (η) is strictly applicable only to Bingham plastics, while plastic viscosity is used for pseudoplastics, etc. It is calculated, however, in the same way, by η or $\mu_p = 2\mu_{a60} - \mu_{a30}$ centipoises.

The pressure drop is then calculated from the standard friction factor-Reynolds number plots or from the equation given above for Newtonian fluids.

Bingham plastics, pseudoplastics and thixotropic fluids will give rather higher initial pressure drops on starting flow than Newtonian fluids, but the pressure drops decrease rapidly as the flow rate increases. Thus, the starting load on pump motors used for the former will be rather higher than usual, and it may be necessary to oversize slightly for this reason. This is of little consequence except for positive displacement pumps. A further point of importance is that Bingham, pseudoplastic and thixotropic fluids are more liable to result in cavitation in pumps than other fluids. For this reason the suction head should be as high as possible.



Example 2

Consider the fermenter mash of the previous example. Suppose that this (for the sake of convenient figures) is to be pumped through a 1 ft diameter pipe at 1 ft/sec. Compare the pressure drop per foot length of pipe calculated by the three methods given above.

Method 1

From the data given in the first example,

$$\mu_p = (2 \times 84) - 137 = 31 \text{ centipoises.}$$

$$\tau_y = 0.6\,(137 - 84) = 31.8 \text{ dynes/cm}^2$$

Then $$\mu_E = \frac{16.7\,\tau_y D}{u} + \mu_p$$

$$= 530 + 31 = 561 \text{ centipoises.}$$

Taking the specific gravity of the mash as approximately unity,

$$N_{Re} = \frac{D\,u\,\rho}{\mu_E} = 165$$

From the standard Reynolds number-friction factor charts, at $N_{Re} = 165$, $f = 0.09$.

Method 2

$$\text{Shear rate in pipe} = \gamma = \frac{2\,u\left(\frac{1}{n} + 3\right)}{D}.$$

As in the first example, $n = 0.275$.

Therefore $\gamma = 13.28 \text{ sec}^{-1}$.

From the plot of μ_a against η, at $\gamma = 13.28$, $\mu_a = 200$.

The modified Reynolds number $= \frac{D\,u\,\rho}{\mu_a} = 464$

Then for pseudoplastic fluids

$$f = \frac{4}{N_{Re}}\left(\frac{3n+1}{n}\right) = 0.06.$$

Method 3

Consider the mash as a Bingham plastic, as an approximation to pseudoplasticity. (This assumption normally makes for design erring on the safe side.)

$$\text{Then } Pl = \frac{100\,\tau_y D}{\mu_p \times u} = \sim 100.$$

$$\text{The modified } N_{Re} = \frac{Dup}{\mu_p} = 3000.$$

From Fig. 7, at $Pl = 100$ and $N_{Re} = 3000$ $f = 0.09$.

The pressure loss per foot of pipe run is then calculated from the Fanning friction factor, in the usual way as for Newtonian fluids. In this case, methods 1 and 3 give friction factors (proportional to pressure drop) which are 50 per cent greater than method 2, and method 3 is known to give pressure drop figures on the high side. In normal design practice, with this type of fluid, agreement by different methods to a degree better than this would not be expected.

(*c*) *Flow of Non-Newtonian Liquids through Pipe-fittings, etc.* Very little has been published on the effect of tees, elbows, etc., on the flow of non-Newtonian liquids. For such fluids in turbulent flow, however, the position seems relatively clear. The normal methods used for Newtonian fluids may be used for computing head through expansions, contractions, etc., where these calculations do not involve the use of a viscosity term. For determining the equivalent length of tees, elbows and bends, the normal viscosity terms should be replaced by the effective viscosity, μ_E. Flow of highly viscous non-Newtonian fluids is rarely turbulent, however.

The use of μ_E appears to be unsatisfactory for determining expansion and contraction losses for viscous flow, and for losses through bends, elbows and tees. Reference should be made to a paper by McMillen[13] for these calculations.

4. Effect of Temperature on Viscosity

The viscosity of liquids decreases with increasing temperature, while that of gases increases with temperature rise. For Newtonian liquids, the viscosity is related with good accuracy to the temperature (T°C) by a logarithmic law:

$$\log_{10} \mu = -KT + C$$

where K and C are constant.

Thus, by measuring viscosity at about four temperatures, viscosity can be plotted against temperature on semi-log paper to permit interpolation for other temperatures. Extrapolation beyond the limits of measurement is also usually permissible over a limited temperature range.

In the case of non-Newtonian fluids, it is always safest to measure the properties of the fluid at the desired temperature. Where this is not convenient, interpolation of results is usually safe enough, but extrapolation should never be attempted.

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A RECTIFYING COLUMN FOR DIFFICULT SEPARATIONS

The Kuhn rectifying column, which was developed over a period of years by Professor W. Kuhn, of Basle University, has been adapted to industrial requirements by Sulzer Bros. working in co-operation with the inventor. The Kuhn column offers advantages wherever difficult mixtures have to be separated and conventional methods would require extremely long columns

by MAX HUBER

A. A Few Basic Concepts

THE brief review of the basic concepts of rectification which we shall give here lays no claim to completeness, and the serious student is referred to the literature.[1, 2]

Liquid mixtures can generally be separated by rectification. Before enlarging on this, however, we must state what is meant by separation and must specify the units in which it is measured, as there is no standardized terminology in this field, and mathematicians, chemists and engineers often use different designations.

Separation Factor

Separation is said to take place when the mol fraction of a component of a mixture undergoes a change in space. According to this definition, separation is therefore the sorting of different substances, whereas in normal usage it may often denote the division of the same substance.

We shall restrict ourselves here for simplicity's sake to the consideration of binary mixtures, designating the mol fraction of the more volatile substance $x_1 = x$, and that of the less volatile substance $x_2 = 1 - x$. Two examples of separations are shown diagrammatically in Fig. 1. The separating elements shown—i.e., the devices in which separation takes place—differ in that element 1b communicates with the outside, while element 1a is entirely closed. In both examples separation takes place in one dimension (or direction) only, which is a feature of most separating processes, as the other two dimensions are required to give the process a cross-section, i.e., a throughput. In the calutron, on the other hand, separation takes place in two dimensions, which offers the advantage that polynary mixtures can be separated continuously in one operation. In return, however, the feed stream can only be unidimensional, which means that the quantitative performance is small.

In closed separating elements, the degree of separation can be indicated by two mol fractions, for instance x_a and x_b, or x_a and $\Delta x = x_b - x_a$. This formulation, however is neither convenient nor informative as a measure of separation. Much more useful is the separation factor q, with which we can characterize a separation by a number indicating the degree of separation taking place. The separation factor is defined as follows:

$$q = \frac{\left(\frac{x}{1-x}\right)_b}{\left(\frac{x}{1-x}\right)_a} \qquad \ldots.(1)$$

It follows from the defining equation that the separation factor will be q^s if the operation is repeated s times. The fact that the separation factor is fairly complicated in form can be explained as follows:

(a) The mol fraction which we use as a measure of relative concentration is mathematically speaking not symmetrical, as it is limited upwards. If we used the molal ratio $R = \frac{x}{1-x}$, the separation factor would be simply $\frac{R_b}{R_a}$.

(b) The difficulty of a separation can only be measured with reference to a separating process. It is in the nature of most separating processes, however—they are known as "statistical" processes—that they are based on the trans-positions of two molecules. Under otherwise constant conditions, therefore, the degree of separation is proportional to the number of changes of place between non-identical molecules (changes of place between identical molecules do not constitute separation). Expressed as an equation, this means that:

$$\frac{\Delta x}{\Delta z} = x(1-x)\ \text{const.}$$

or

$$\frac{\Delta x}{x(1-x)} = \Delta z\ \text{const.}$$

and, after integration:

$$\ln q = z\ \text{const.}$$

In open separating elements, the degree of separation is determined by the separating capacity, i.e., by the separation factor and the throughput.

Single-process Factor

Rectification is based on the fact that a state of separation normally exists between vapour and liquid when these are in equilibrium, this state being characterized by the single-process factor α. For ideal mixtures α is equal to the ratio of the vapour pressures of the two components:

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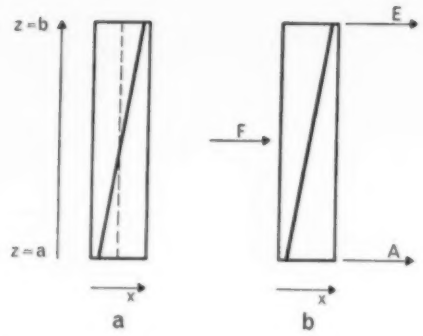

Fig. 1. (a) A closed separating element. The broken line represents composition before, the full line after, separation. The element is characterized by the separation factor. (b) An open separating element. A feed stream F of composition x_F is split into product E and bottoms A of mol compositions x_e and x_a respectively. The element is characterized by its separating capacity (separation factor and throughput).

$$\alpha = \frac{p_1}{p_2} \qquad \ldots.(2)$$

In practice α is often replaced by $\varepsilon = \ln \alpha$, which KUHN terms the separation parameter (for $\varepsilon < 0.3$, ε is approximately equal to $\alpha - 1$). By applying Trouton's rule, we can replace Equation (2) by:

$$\varepsilon = 10.7 \frac{T_s}{T_p} \qquad \ldots.(3)$$

where ΔT_s = difference in boiling point at 760 mm Hg;
T_p = boiling point at distillation pressure (°K).
With non-ideal mixtures α is normally a function of x.

Fenske Number n_F

The separation factor is a measure of the degree of a separation. The difficulty of the separation can only be exactly indicated if we imagine an actual separating method with the single-process factor α. A reasonable measure of the difficulty of separation is the Fenske number, or number of stages, which tells us how many times we must repeat the single equilibrium stage in order to obtain the desired separation factor q:

$$n_F = \frac{\ln q}{\varepsilon} \qquad \ldots.(4)$$

n_F can also be graphically determined by the McCABE-THIELE method, which is particularly useful when α is not a constant.

Symbols Used

x = mol fraction;
q = separation factor;
z = longitudinal co-ordinate;
α = single-process factor;
ε = separation parameter ($\varepsilon = \ln \alpha$);
n_F = Fenske number (number of stages);
n_W = number of transfer units;
n_t = number of theoretical plates;
n = specific number of stages per metre;
G = gas flow up the column (boil-up);
v = reflux ratio;
D = diffusion constant, cm²/sec;
Q = heat input (watts).

Rectification Processes

The degree of separation achieved in a single stage can be increased at will in a rectification column by allowing the liquid and gaseous phases to flow in countercurrent, so that they are in contact with each other and equilibrium can be established between them (Fig. 2). Exact theoretical treatment of this problem is fairly complicated, so that we shall not embark upon it here, referring the reader instead to the neat presentation given by COHEN.[1] The theory shows that there are three parameters in addition to the initial and final concentration and the separation parameter, viz.

G The gas flow (mol/sec) in the z-direction. This value decides the cross-section of the installation. We can pass more or less material through a given cross-section according to the design of the column, the upper limit being set by the fact that from a certain throughput upwards (flooding limit) the liquid is entrained by the vapour and counterflow ceases to be possible.

v The reflux ratio is the ratio between the reflux L and the product E, or, in other words, the ratio in which the rising gas stream G splits up into L and E. A simple material balance between the amount of substance entering the bottom of the column and the amount of product collected shows that there is a minimum reflux ratio for every separation:

$$v_m = \frac{1}{\alpha - 1} \frac{x_E - x}{x(1-x)} + \frac{x_E - x}{x} \qquad \ldots.(5)$$

Below this ratio the desired separation cannot be carried out even with an infinitely long column. The ratio $s = \frac{v}{v_m}$ is known as the economy factor. The column cross-section, the heating and condensing surfaces and thus the energy consumption all increase with increasing s, but at the same time the required length of column is reduced.

n_w The number of transfer units is an abbreviation of the following expression:

$$n_w = \frac{k}{G} z \qquad \ldots.(6)$$

where k is the constant for the material exchange between the two phases:

$$\frac{1}{k} = \left(\frac{b}{Dc\sigma}\right)_g + \left(\frac{b}{Dc\sigma}\right)_l \qquad \ldots.(7)$$

with b = diffusion path to phase interface;
D = diffusion constant;
c = concentration;
σ = exchange surface per unit length.

The number of transfer units n_w of a packed column corresponds to the number of theoretical plates n_t of a plate column and can therefore be determined graphically by the McCABE-THIELE method (Fig. 3).

For a packed column n_w can rarely be calculated, as the factors contained in it are not sufficiently known. However, it can easily be determined by experimental means, for at $v = \alpha$ we have:

$$n_w = n_t = n_F$$

i.e., if we express the degree of separation measured in a column at $v = \alpha$ by the Fenske number, we obtain exactly n_w. The separating capacity of our column, at a given length, becomes greater as the specific number of stages $n = \frac{k}{G}$ increases. The latter is the ratio of the material transport between the two phases and that taking place along the column. As G is given for a particular separation by the reflux ratio, we can improve a column only by increasing k, or in other words by shortening the diffusion

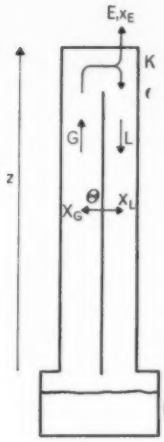

Fig. 2. Vapour G from still B rises and is condensed wholly or in part in condenser K. Condensate L flows downwards and vapour E leaves the column. The material exchange—between the two phases (the vertical line represents the phase interface) depends partly on the separation factor between X_G and X_L, and decreases as this factor approaches the single-process factor.

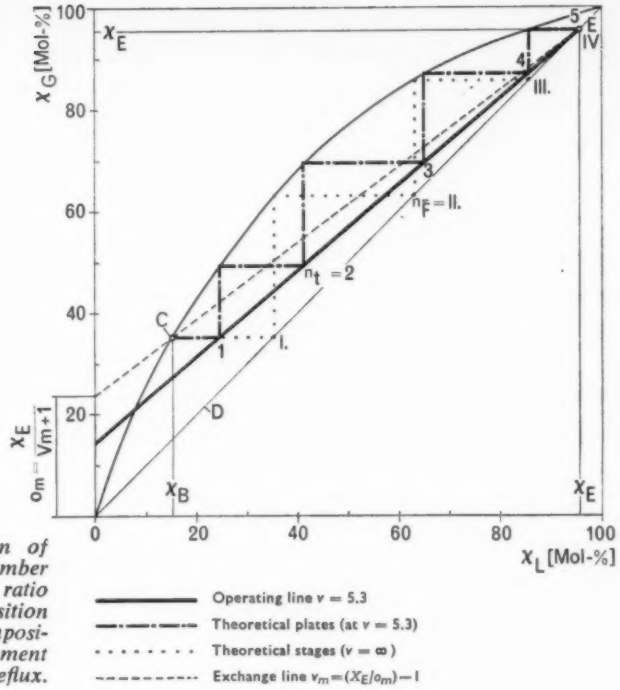

Fig. 3. McCabe-Thiele *determination of the minimum reflux ratio v_m and the number of theoretical plates n_t. With a reflux ratio of 5.3 and $n_t = 5$, the product composition $x_e = 0.95$ mol/mol and the bottoms composition $x_b = 0.15$ mol/mol. This enrichment corresponds to $n_F = 4$ stages at total reflux.*

Operating line $v = 5.3$
Theoretical plates (at $v = 5.3$)
Theoretical stages ($v = \infty$)
Exchange line $v_m = (x_E/o_m) - 1$

path and enlarging the phase interface.

The n_w required for a given separation can be calculated[2] and fixes the length of the column required. The magnitude of n_w will differ according to the reflux ratio adopted, as a rule becoming smaller as the reflux ratio is increased. The minimum value of n_w is n_F.

Calculation of a Column

The attempt must be made to find the best possible column for any given separating operation. For this purpose a variety of factors must be taken into account, such as the size of the installation, the costs of power and water and wage levels. In the final definition the quality of the column is judged by the costs of separation.

Technical Aspects of Rectification

Generally speaking, there are two types of rectifying column which differ in the method of creating the phase interface required for material transfer:

A. The interface is created by passing the liquid step-by-step in countercurrent through the gaseous phase. Examples: bubble-plate and sieve-plate columns.

B. The liquid is distributed over a large area.

(a) The surface is formed by an irregular structure of packings.
Example: packed columns. These often have the disadvantage that the number of stages decreases with increasing column diameter, which is explained by channelling. These phenomena are obviated in the *Kuhn column*, in which several parallel small-diameter tubes are used instead of a single large-diameter tube.

(b) The surface is formed by a regular structure of vertical walls.
Kuhn film-type column, wetted-wall column.

The various designs now in use show that the ideal solution to the problem has yet to be found. The nearest approach to it so far is the film-type column, but a satisfactory embodiment of this for large-scale engineering purposes is still being sought.

Sulzer columns on the Kuhn system belong without exception to Type B. The laboratory column for 100 to 5000 cm³ of material, which is described in the following section, is a film-type column.

Kuhn columns filled with high-efficiency packings are built for industrial applications. The division of the column cross-section into several tubes offers the advantage that the results of pilot tests conducted in a single tube can be safely applied to larger plants. On the other hand, the material has to be uniformly distributed over the various tubes. A plant used for the concentration of D_2O is described by way of example in Section C.

B. The Sulzer Film-type Column on the Kuhn System

This column is intended for research and laboratory work and has several special features. Thus the number of transfer units n_w can be adjusted between 1 and 300 and can consequently be adapted to all separations required in the laboratory, which can also be carried out under conditions accurately determined in advance.

All the important factors involved in rectification are known and exactly defined.

Description of Column

Fig. 4 shows the experimental column in the Sulzer laboratory. It consists of three main parts: the body of the column, the work-table and the control panel. Fig. 5 is the flow sheet.

The body of the column consists in essentials of 61 empty tubes with an inside diameter of 4 mm and a length of 2 m. The mixture in still 1 is evaporated by an electric heating system 2. The vapour rises, evenly distributed over the various tubes, till it reaches the zone of the boiling dephlegmator 3, where it is partly or wholly condensed, so that it flows downwards through the tubes in the form of a thin film of liquid. It is important for efficient separation that the reflux ratio should be the same in all the tubes, or in

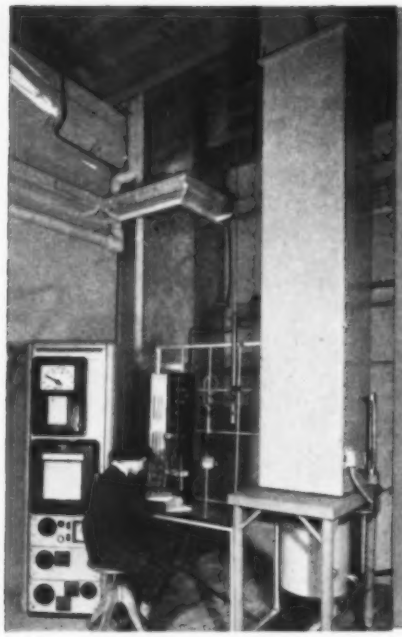

Fig. 4. A film-type column in operation.

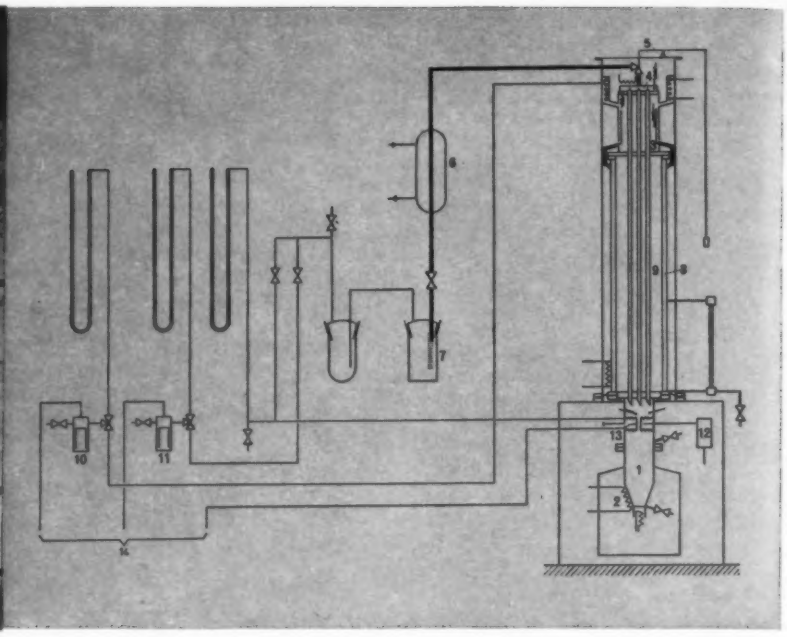

Fig. 5. Diagram of film-type column. 1, *Still;* 2, *Still heater;* 3, *Dephlegmator;* 4, *Take-off space;* 5, *Product valve;* 6, *Condenser;* 7, *Receiver;* 8, *Jacket;* 9, *Vacuum insulation;* 10, *Manostat;* 11, *Manostat receiver;* 12, *Pressure transmitter;* 13, *Differential-pressure manostat;* 14, *Pump.*

other words that the same amount of product should be withdrawn from all tubes. This end is achieved by passing the uncondensed vapour through calibrated capillaries having a much higher resistance than the rectifying tubes. The vapour flows through the capillaries into take-off space 4, whence it goes through product control valve 5 to condenser 6 and is finally collected in receiver 7. To ensure adiabatic operation, the body of the column is surrounded by a boiling jacket 8 and the space 9 between the tubes is evacuated. All parts coming into contact with the substance distilled are of stainless steel. The column is built for temperatures up to 300°C and absolute pressures up to 10 kg/cm². In the standard design, however, the fittings and instruments are intended only for 200°C and 2 kg/cm² abs. The column can be used for all substances that wet stainless steel without attacking it, which includes almost all organic materials.

The capacity of the still is 5 litres. The hold-up of the column is 30 to 50 cc.

Operation

The temperature in the column is roughly equal to or just above that in the dephlegmator, and for simplicity's sake dephlegmator and boiling jacket are therefore kept at the same temperature, which can be set to any desired value (up to the normal boiling point of the dephlegmator liquid) by means of a manostat 10.

The pressure in the dephlegmator section of the column tubes is determined by the temperature and by the product contained in them, and since the pressure drop along the column can generally be neglected, it is equal to the still pressure, which is measured by way of a transmitter 12. A change in pressure shows that the product in the dephlegmator section has changed in composition, or in other words it indicates the commencement of a new fraction. A pressure change also brings about a change in the boiling point in the still, the level of which depends on the composition of the still liquid.

The amount of product is regulated by product control valve 5 and by the difference in pressure between the receiver and the column, i.e., by the pressure difference at the product control valve.

The column is normally operated by hand, but can also be operated automatically in either of two ways:

(a) With a fixed reflux ratio, which is set by hand by means of the product control valve and the pressure difference. The latter is then kept constant by a differential-pressure manostat 13.

(b) With the reflux ratio regulated so that pure product is obtained. For this purpose the receiver pressure is set with manostat 11 to a fixed value just below that of the desired product at the dephlegmator temperature, while the reflux ratio is adjusted approximately to the correct level with the product control valve. Should this ratio be too small, so that the head product is not pure, the pressure will fall, and with it the amount of product collected, until the desired purity is re-established as a result of the consequent rise in the reflux ratio. When no further pure product can be withdrawn, collection ceases.

Number of Transfer Units n_w (Number of Theoretical Plates)

The number of transfer units can be calculated and is generally inversely proportional, for a given mixture, to the vapour velocity, which can be calculated from the heat input. Provided that the steam flow is laminar, which is usually the case in distillation, and that the diffusion resistance in the liquid phase is much smaller than in the vapour phase, the following simple formula applies:

$$n_w = 15.4 \frac{RZ}{Q} D_0 \left(\frac{T}{273}\right)^{32} \quad \ldots.(8)$$

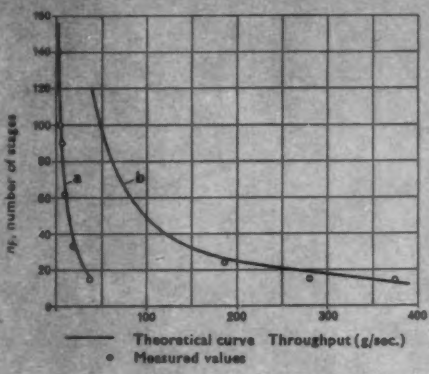

Fig. 6. Dependence of n_F on film throughput. Curve a: enrichment of heavy carbon C^{13} in a column with 100 tubes, length 800 mm, 4 mm i.d., by rectifying CCl_4 m.wt. 153, b.pt. difference of pure components $\Delta T_s = 0.033°K$, $\epsilon = 0.0013$. Curve b: N-heptane-methyl-cyclohexane mixture, enriched in a Kuhn column, 136 tubes, length 3000 mm, 8 mm i.d., $\Delta T_s = 2.43°K$, $\epsilon = 0.07$.

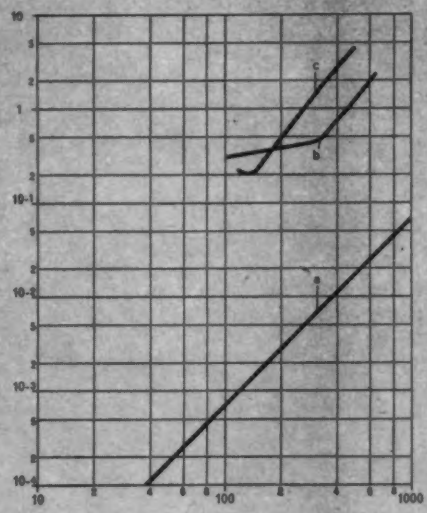

Fig. 7. ΔP vs. throughput at normal pressure, calculated for 50 stages. Curve a: Kuhn column. The sum of the tube cross-sections corresponds to a column of 24 mm i.d. Curve b: Stedman column, 25 mm i.d.[5] Curve c: Wire helices (4 × 4 mm), column of 24 mm i.d.[6]

where R = number of tubes;
Z = length of column (cm);
T = dephlegmator temperature (°K);
Q = heat input to still (watts);
D_0 = diffusion constant at 760 mm Hg and 0°C.

It will be seen from this equation that the number of transfer units does not depend on pressure. However, since the separation parameter usually increases with decreasing pressure, it is an advantage to work at low pressures.

Fig. 6 shows in two examples that Equation (8) is satisfactorily fulfilled.

Maximum Loading of the Film-type Column

The limiting heat input Q_{max} is given by the maximum vapour velocity in the tubes, at which the liquid film is entrained upwards and the column therefore flooded. The following equation holds good:

$$Q_{max} = 46(r - 1.0)\, Z\, p^{\frac{1}{2}} \qquad \ldots . (9)$$

where r = inside radius of the rectifying tubes;
p = working pressure in column [kg/cm² abs.].

The accuracy of Equation (9), according to experiments carried out by PROF. KUHN, is of the order of 20 per cent for tube radii from 1.5 to 10 mm at pressures from 0.01 to 1.5 kg/cm² abs. and for liquid mixtures having molecular weights from 18 to 150.

Pressure Drop

A pressure drop Δp is caused in rectifying columns by plates, packings and the like. If the absolute pressure at the head of the column is p, the pressure in the still will be $p_1 = p + \Delta p$. The boiling point in the still will also be higher, since it must correspond to the pressure p_1.

The separation of organic liquid mixtures by rectification usually requires a large number of stages. Moreover, mixtures of this kind are often stable only up to certain temperatures. There is therefore every reason to carry out rectification in a column with the smallest possible pressure drop, so as to keep down the boiling point.

The pressure drops of conventional columns using plates or packings are naturally greater than that of the KUHN column with its empty tubes. The drop in a bubble-plate column of 20 theoretical plates, for instance, is about 600 mm w.g., or about 400 mm w.g. in one of the common types of packed columns.

The advantages of the film-type column are also apparent from a comparison of its pressure drop with those of laboratory models of other designs constructed for specially low losses (Fig. 7).

In packed columns the presure drop increases with the number of stages, while in the film column the opposite is the case. Here the boiling temperatures in the head and the still are practically equal, as the pressure drop in the empty rectifying tubes is negligibly small.

The pressure drop of the film column can be calculated from the laws applying to vapours flowing in smooth tubes.

Choice of Number of Stages

The number of transfer units required for any separation can be calculated for a given reflux ratio. This ratio can be chosen as desired between v_m and ∞, and the number of stages then lies between ∞ and n_F. Each separation can therefore be carried out in an infinite number of ways; but the object will normally be to select the alternative offering a maximum quantity of product. Exact calculation is usually complicated, and frequently an approximation has to be accepted because the material properties are not sufficiently known. The following simple rule, however, will usually give good results. We first calculate v_m and n_F with Equations (4) and (5) and then assume that

$$v = 1.5\, v_m$$
$$n_w = 1.5\, n_F$$

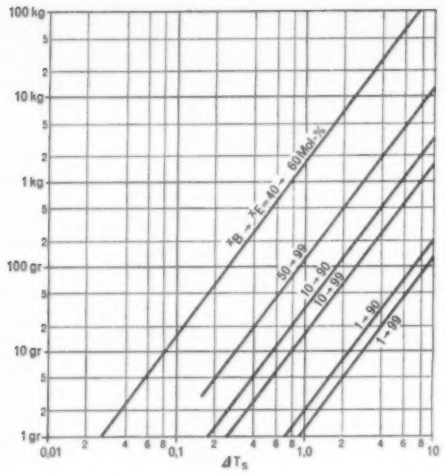

Fig. 8. Performance of Sulzer film-type column employing the Kuhn system. The diagram is based upon a distillation temperature of about 90°C and a m. wt. of components of about 100. Performance depends markedly on the difference in boiling points ΔT_s as well as on the values of x_b (assumed constant) and x_e. Each straight line refers to a definite pair of x_b and x_e values.

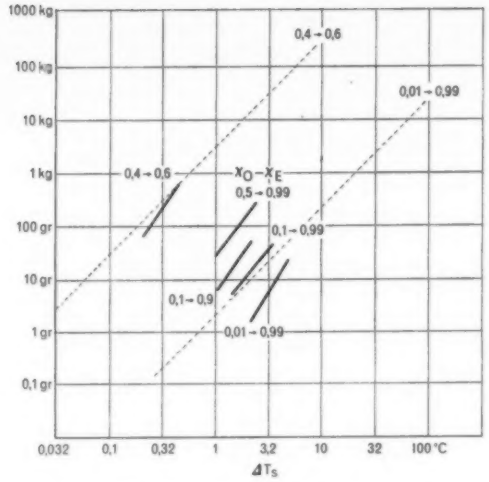

Fig. 9. Performance of a single tube fractionating column 4 mm i.d. 200 mm length filled with 3-mm Dixon rings. The x_o and x_e values are shown at the top and bottom of each curve. For comparison, the performance of a column with 100 tubes each 4 mm i.d. 200 cm length is represented by two broken straight lines.

When polynary mixtures have to be separated, they may be treated in a first approximation as binary mixtures, the most volatile constituent being regarded as the first component and the balance as the second component.

The quantitative performance of the column can be estimated from Figs. 8 and 9. In Fig. 9 the performance of a packed column of the same overall cross-section, as experimentally determined by PROF. KUHN,[2] is entered for purposes of comparison. It is clear from this figure that the range of application of the film-type column is much larger than that of the packed column or, for that matter, the plate type.

Applications

The laboratory column has many different uses:

(a) Analytical and preparative separations for quantities of 200 to 5000 cc. The small hold-up is here an advantage. As it is possible to select the number of transfer units between 1 and about 300, the column can be adjusted extremely well to a wide range of separations, which can be carried out under conditions accurately laid down in advance.

(b) Pilot tests. Tests with different numbers of stages reveal the number best suited to a given separation, a procedure which is particularly valuable with polynary mixtures that are difficult to calculate in advance. With other types of columns every test would have to be carried out with a different length of column corresponding to the different number of transfer units.

(c) Measurement of the material exchange constants under various sets of conditions with the aid of Equation (6).

(d) Enrichment by an exactly defined factor. PROF. KUHN[2] has shown that, in rectification with a large number of stages and a small reflux ratio, the enrichment depends only on the separation parameter and the reflux ratio. The latter, unlike the number of stages, can be very accurately measured, so that the separation is exactly defined. By this method separation parameters which are too small for direct measurement can be ascertained. It is also possible to enrich small amounts of substance in mixtures up to the point at which they are easily amenable to analysis.

(e) For practical instruction purposes the column offers the advantage that all factors of importance for the understanding and calculation of the rectification process are exactly defined.

C. Installation for Concentrating Heavy Water by Rectification

The final concentration of heavy water by rectification is economically advantageous, although the single-process factor is here smaller than in other commercial processes. The explanation of this is that the power consumption for final concentration (from about 10 mol per cent) is small compared with that for the previous stages, and that rectification plant is cheaper to install and run than that required for other processes.

The column described below is intended for the reconcentration of D_2O in the event of accidents in a reactor plant. The quantities of water to be treated and their concentration can, of course, only be estimated, but the following specifications were agreed upon in discussions with the clients:

Annual production (8000 hr): 10,000 kg,	99.8%	D_2O
Feed concentration:	70-95%	D_2O
Head concentration:	under 5%	D_2O

The plant will be fully automatic in operation. It will also be capable of treating D_2O with a lower initial concentration by repeated rectification.

Column Design

A study of the requirements revealed from the outset that a Kuhn column with high-efficiency packings (subjected to a special Sulzer treatment) would be the most suitable for this installation. Data on the number of stages and the pressure drop at various boil-up rates and pressures were available for use in the calculations from experiments carried out in part by PROF. KUHN and in part by Sulzer Brothers.

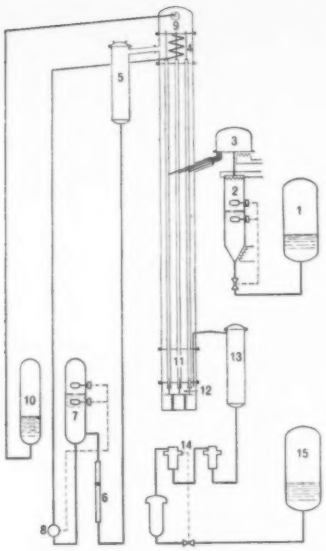

Fig. 10. Diagram of a Sulzer heavy-water column. 1, Feed tank; 2, Evaporator; 3, Distributor; 4, Head column; 5, Condenser; 6, Rotameter; 7, Reflux reservoir; 8, Pump; 9, Head tank; 10, Product receiver; 11, Evaporator; 12, Product valves; 13, Condenser; 14, Density meters; 15, Bottoms receiver.

The separation parameter and the specific load capacity of the packings are both dependent on pressure, the former decreasing and the latter increasing with increasing pressure. The pressure consequently had to be chosen to give optimum column characteristics.

The head pressure was fixed at 100 mm Hg, as at this pressure the packing volume is at a flat minimum. The value chosen lies only just above the minimum, so that the number of tubes can be kept small.

As a result of the same minimum requirement, the separation had to be carried out with $n_w = 450$ transfer units including the necessary safety allowances. At a specific number of 50 transfer units per metre, this meant that the column must be 9 m long. As the data on the number of transfer units was obtained from measurements made in shorter tubes, a pilot test with a 9-m tube was conducted as a precautionary measure. The reflux ratio in the stripping section is $v = 50$. This means that about 50 kg of vapour is needed for every kg of D_2O produced. As the column was designed for the maximum separating duty, i.e., for a feed concentration of 70 per cent, the performance improves at higher feed concentrations and is about 40 per cent higher at a concentration of 95 per cent D_2O.

Column Diagram (Fig. 10)

The feed ($H_2O + D_2O$) is stored in reservoir 1 and is supplied as required to evaporator 2. The vapour produced in the latter goes by way of a distributor 3 to the various tubes, in which it rises till it reaches head 4 and passes into condenser 5. From here it flows in liquid form through flowmeter 6 and into reflux reservoir 7. A pump 8 returns the liquid to head container 9, in which the pressure is higher than in the head of the column itself. While the head product enters receiver 10 through an overflow, the reflux passes through a distributor into the various tubes and flows down them into the bottom section 11, where it evaporates completely. The bottom product (D_2O) is collected periodically in vapour form from the individual tubes through valves 12. It is then condensed in condenser 13 and flows by way of density meters 14 into receiver 15.

Control

The reflux is regulated by altering the differential pressure between the reflux reservoir and the head of the column. It is measured by rotameter 6.

In normal operation the feed and boil-up rate are constant and the product control system ensures that the maximum possible amount of bottom product is withdrawn. The D_2O concentration of all product collected is checked by measuring the density. As long as the concentration is above a certain value, withdrawal is increased; below this value, it is reduced; and if it falls below the admissible minimum, withdrawal is stopped and an alarm sounds. The column is fitted with safety devices which take action if the water, steam or power supplies should be interrupted or if individual components should fail, in which case either an alarm sounds or the column is shut down. Supervision is limited to a daily check of the temperatures shown on a recording instrument and of the rotameter.

Constructional Material

The column and fittings are of copper, while the collecting equipment for D_2O is of stainless steel throughout.

The column (Fig. 11) and the fittings (arranged in groups) were assembled ready for service in the Sulzer shops and had only to be connected up on site.

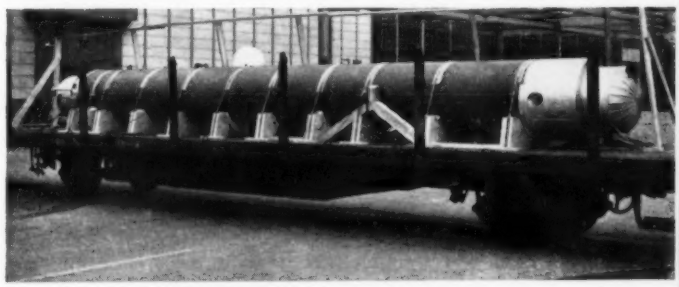

Fig. 11. A heavy-water column ready for delivery.

Comparison with Other Plants

The only comparative data available are those of a sieve-plate column in Savannah River.[3] As these two columns differ very substantially, they can only be compared by converting the data on an appropriate reference basis (see Table I). Comparison shows that the Kuhn column is far superior in respect of the number of plates, hold-up and pressure drop, while its boil-up rate is somewhat lower. If the separation described above had to be carried out in a sieve-plate column, this would have to be 170 m long and would have a working charge of about 1200 kg, or one-eighth of the annual production.

Table I — Comparison of the Kuhn Column with a sieve-plate column in Savannah River

	Savannah River sieve-plate column	Sulzer packed column
Head pressure	100 mm Hg	100 mm Hg
Boil-up rate $\left(\frac{g}{cm^2/h}\right)$	120	100
Number of theoretical plates per m	3	50
Pressure drop (mm Hg per plate)	2.8	0.4
Hold-up per plate × cm^2 (cm^3/cm^2)	4.8	0.34
Weight per plate × cm^2 (g/cm^2)	24.2	11.2

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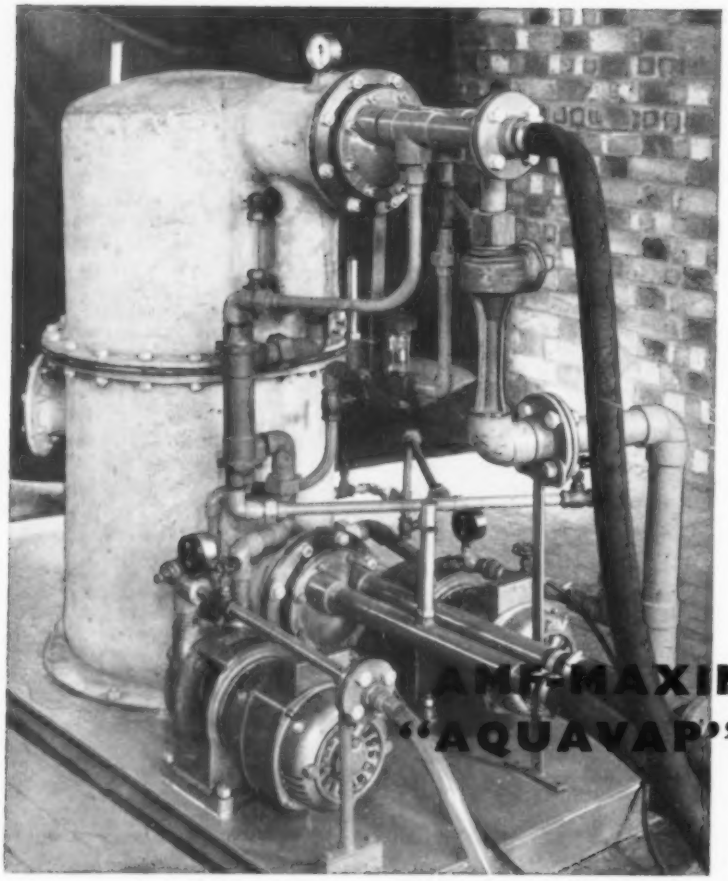


AMF-MAXIM "AQUAVAP" EVAPORATORS

THE problem of obtaining fresh water from saline and other sources at low cost to meet the growing demand caused by the expansion of population and industry is being closely studied in a number of countries, and various processes are being investigated, such as solar evaporation, electrodialysis, freezing, evaporation and distillation. Processes of the latter type have been in operation for many years and more than 10 million gallons per day of fresh water are being produced through them. Some of the plants of this kind have capacities of the million-gallon-per-day order; for example, the multi-stage flash distillation plant in the island of Guernsey. There is, however, a demand for very much smaller units as well, with outputs measured in tens of gallons per day.

Equipment of this kind has been recently introduced into this country and is known as "Aquavap" and is available in three sizes with capacities in the range 300-10,000 gpd.

The units utilize waste heat in engine jackets, or similar sources, having a temperature of 150°F or more. Hence raw water can be converted to fresh water for the cost of operating the pumps and salinity panel. They are compact, lightweight, transportable, virtually automatic in operation and require no highly skilled technical personnel to attend them. The shell is of reinforced glass fibre plastic which is light, durable and corrosion resistant.

The diagram shows the flow cycle. The hot, circulating water is pumped through the lower heat exchanger (raw water heater) and is returned to the circulating system. This water supply is not affected in any way, except that some heat is removed.

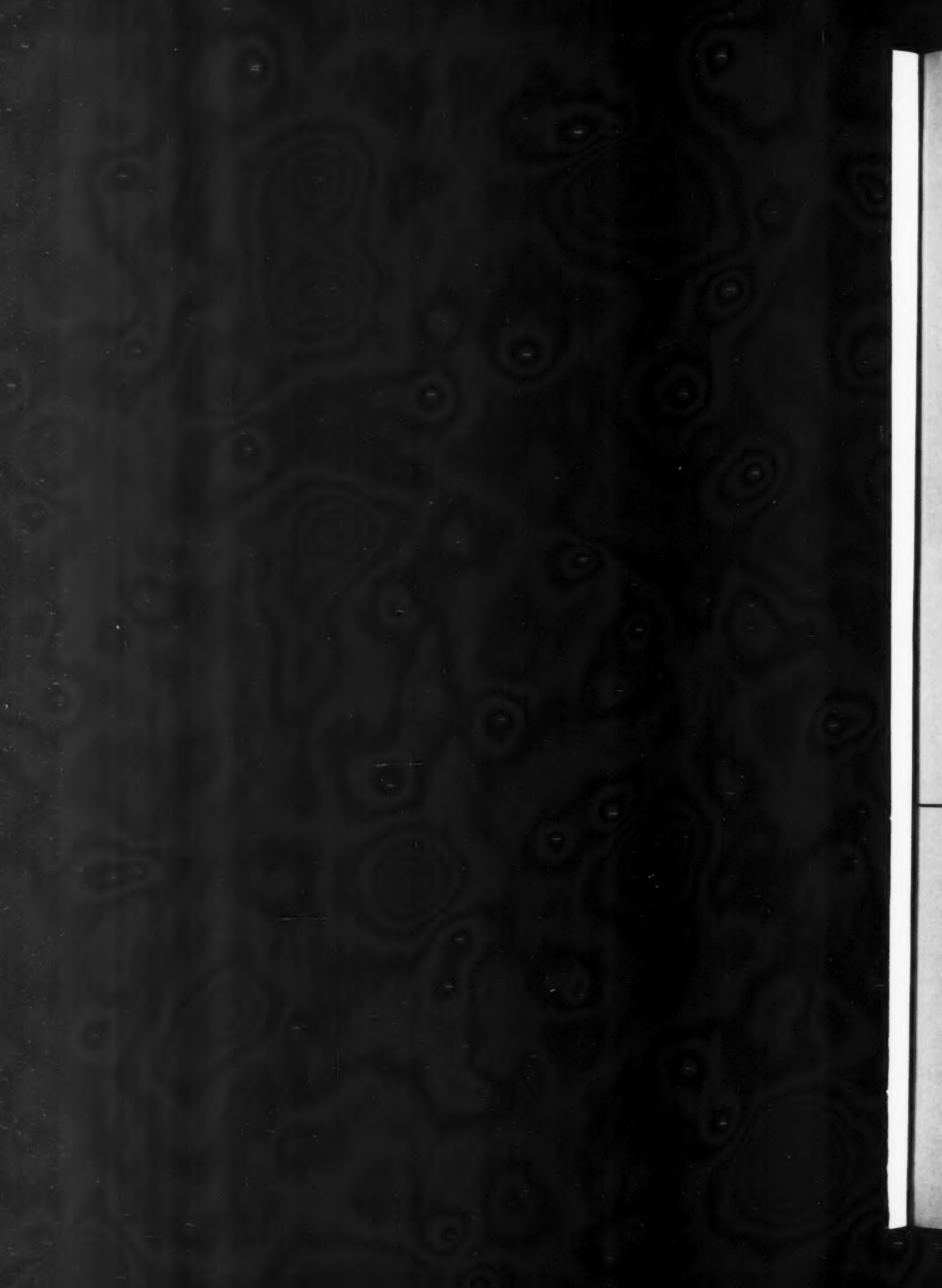
Raw water is pumped through the condenser and discharged. Air and non-condensable gases are removed by a motor-driven vacuum pump, or a jet vacuum pump on the smaller units.

The feed water supply flows from the distiller condenser outlet into the evaporator shell. The excess feed (waste water) is drawn off from the shell by the waste water pump and discharged.

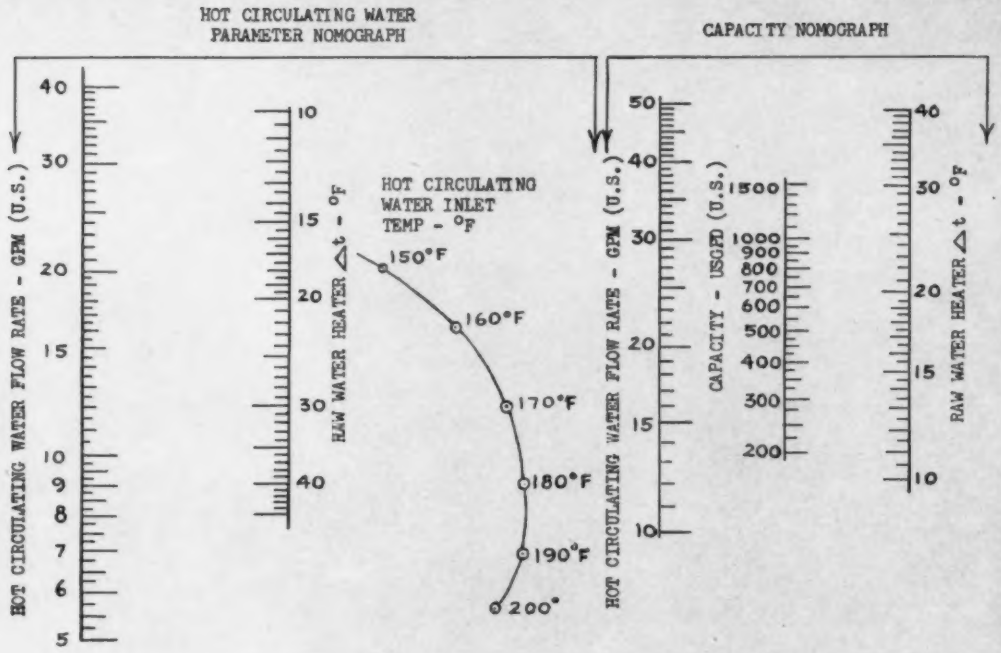
The raw water boils in the lower section of the evaporator shell. The vapour produced passes through a specially designed separator to the distiller condenser tubes, where it is condensed, and the resultant fresh water collects in the hot well below the condenser. The fresh water is pumped from the hot well to storage.

Model No.	VJ 20	VP 150	VP 250
Capacity Range	1.3–3.7 ton/day	9.3–27.8 ton/day	15.5–46.3 ton/day
Electric power required in kW	0.75	3.0	3.75

The "Aquavap" has been used in off-shore and land-based oil drilling stations, chemical, food and pharmaceutical processing, paper mills, mines, etc., and for concentrating radioactive effluents. The units are now manufactured in the U.K. and available from AMF Ltd., 4-6 Savile Row, London, W.1.



STIMATED PERFORMANCE OF VJ-20 AQUAVAP



Constants

I. 85°F Raw Water Supply.
II. 23 gpm Raw Water Flow Rate.
III. 0.005 fouling for all heat exchangers.
IV. Raw Water Heater:
Area—17 ft²
ΔP—1.8 psi at 3.57 ft/sec.
Flow rate—25 gpm.
V. Distiller Condenser:
Area—22 ft²
ΔP—2.5 psi at 3.57 ft/sec.
Flow rate—25 gpm.

Procedure

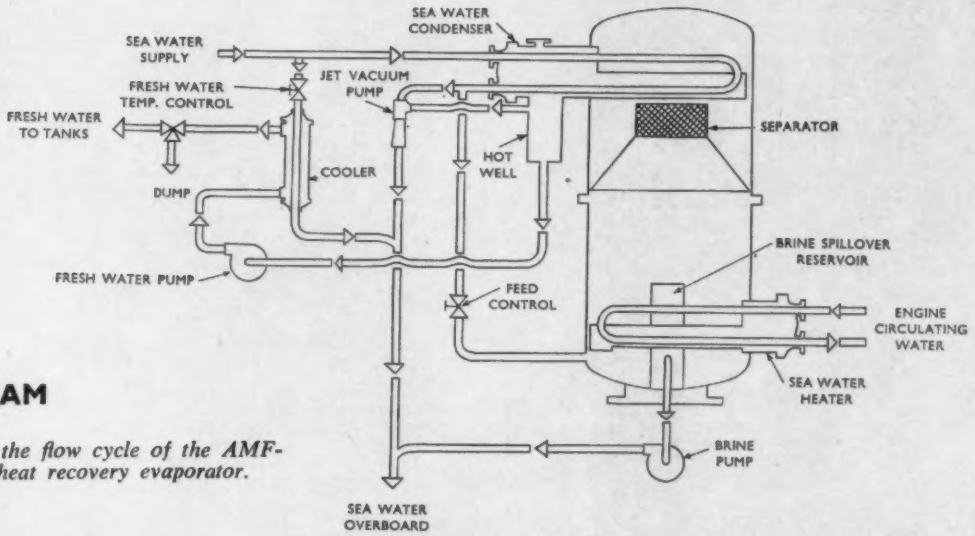
(1) Determine hot circulating water flow rate and temperature (use 0.50 gpm/bhp if actual flow cannot be determined); enter these data in hot circulating water parameter nomograph; draw straight line connecting these two points and read raw water heater Δt.

(2) Enter raw water heater Δt and hot circulating water flow rate in capacity nomograph and draw straight line connecting these two points. Read rated capacity directly.

Note: These nomographs are based on U.S. gallons.

Conversion Factors

1 U.S. gall. = 0.833 Imp. gall. = 3.785 litres.
1 Imp. gall. = 1.20 U.S. gall. = 4.546 litres.
I Litre = 0.264 U.S. gall. = 0.220 Imp. gall.



FLOW DIAGRAM

The diagram shows the flow cycle of the AMF-Maxim "Aquavap" heat recovery evaporator.

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AN INTRODUCTION TO AIR-COOLED HEAT EXCHANGERS

The field advantages and disadvantages of large-scale air-cooled heat exchangers are discussed. Various features of design are outlined: choice of control system, design ambient conditions, natural or forced draught, number of fans, and type of header are some of the points dealt with by the author. Cost data are given to permit rough estimates to be made of typical installations. The items of information which a buyer must give are also enumerated.

by R. J. ANDERSON

THE air-cooled heat exchanger is an example of the application to process engineering of a very simple principle. Considering its successful employment by the automotive engineers over a period of 60 years, the surprising thing is not that cooling by air is now becoming widely adopted, but that it took so long for its attractions to be appreciated. In the language of our petroleum and chemical industries, the process flow is passed through a horizontal bank of tubes, and mechanical draught causes the ambient air to pass across these tubes, cooling the flow if it is a liquid or condensing it if it is a vapour. Ambient air is the active coolant and we may therefore call the equipment an air cooler.

The basic form of air cooler is a tube bundle of approximate proportions 8 ft wide by 24 ft long standing on four legs, one at each corner. At each end is a narrow box header, say 8 ft wide by 12 in. deep, depending on the number of rows of tubes (Fig. 1).

There is an inlet nozzle and an outlet nozzle. Heat exchange is arranged according to the number of rows, which is normally between 3 and 8, and the number of passes, which may be from 1 to 12 or even higher. The basic form of tube is a finned tube with an aluminium fin giving a surface ratio of about 17 to 1 to the bare tube surface. On occasions tubes with a lower surface ratio are chosen and sometimes even bare tubes are employed.

The history of static industrial air coolers runs parallel with the development of the oil and gas fields in the south-western states of America. Substantial condensing and cooling loads had to be dealt with by air cooling because the traditional water coolant was not available in these arid areas. Quite soon the efficiency of these air coolers was observed to justify their wider acceptance under conditions where water was by no means scarce. This situation dates back to the late 1930s, and as long as ten years ago complete refinery units were being successfully air-cooled by what we in temperate Europe would regard as ambient air of an uncomfortably high temperature.

Now the reasons for this adoption of air cooling are several, varied and interesting. In giving these reasons some generalizations cannot be avoided, for the sake of brevity.

Advantages of Air Cooling

The prime reason is that an air-cooled installation costs less than a water-cooled installation. Our air coolers are largely factory-made: their erection on site is simple and the amount of site preparation is negligible. Even if the ex-works price of an air cooler is more than twice the price of an equivalent water-cooled shell and tube unit, the fact is that the latter constitutes less than half the overall cost of water cooling. No doubt a factor operating against shell and tube coolers has been the differing corrosion characteristics on product side and water side: measures to combat this are costly and will be known to all through their enforced adoption in recent years. The equipment costs and site engineering costs of circulating water, whether it is once-through or recirculated, are the other factors operating to the advantage of air cooling.

In operating and maintenance costs the difference in favour of air coolers is more marked. It is possible here to quote[1] "Maintenance costs for air fin coolers are presently estimated at one half of that for shell and tube equipment. Such maintenance includes replacement of fan bearings,

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V-belts, external and internal cleaning of finned tubes and a scheduled routine inspection and maintenance of driver equipment. Operating costs generally favour air fin coolers over shell and tube exchangers. Estimate studies of total operating costs made for future expansion of process units have shown possible savings to be as much as 35 per cent." Supporting this statement we find again the lack of conflict between product side and coolant side: the product stream may be conditioned to impart long life to steel tubes without causing season-cracking in non-ferrous trim, which is noticeable by its absence.

These advantages of lower prime cost and saving in operation and maintenance have now been understood and appreciated by the majority of refinery owners and by all the major consultant/contractors. Air coolers have been chosen in the last three years for crude distillation units in the south of Spain and in Slagen on the much cooler Oslo fjord; for reforming units at Mozambique in sub-tropical East Africa and at Martigues in Southern France; for such places as might surprise us, like Arabia where the design ambient air temperature is 120°F or Aruba, which is an island only 15 miles by 5.

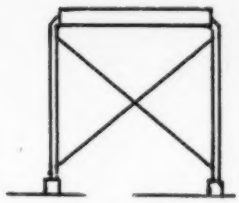
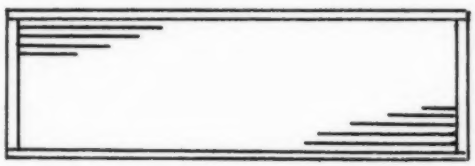
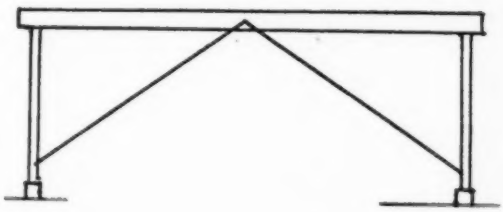


Fig. 1. Arrangement of an 8 ft × 24 ft air-cooled heat exchanger.





Variations in Design

Here in the British Isles conditions are favourable for air cooling. There is indeed lots of water, but the cost of using it is high. So we find completely air-cooled refineries at Whitegate in Ireland and Milford Haven in Wales, extensive plants cooled by air at Fawley and planned for air cooling at Kent and Coryton, while the leading chemical manufacturers find wide scope in its applications.

Air coolers provide a fascinating study to those who are interested in them, because of the variations in possible choice of equipment for a given duty or service. So now we must elaborate a little on the basic picture we drew at the beginning.

Dealing with the tube bundle 8 ft × 24 ft, there is first the option of choosing forced draught or induced draught. Induced draught, with the fan above the tube bundle, has many advantages. It provides an even distribution of air flow, especially for shallow bundles of 3 or 4 tube rows. It has a greater chimney effect, preventing risk of recirculation and giving better heat removal with fans switched off. It furnishes protection from the elements and facilitates accurate control of outgoing product temperature, where this is featured. Induced draught allows more headroom below the bundle for a given column length and bundle elevation and is better adapted to suspended drives without foundations at grade level for mechanical drive. The canopy over the tube bundle is of transition type (Fig. 2).

The alternative forced-draught unit has its fan below the tube bundle and may have box-type plenum chamber with fan ring below or transition hoods. When several small (i.e., narrow) tube bundles carrying separate services are combined into one unit and require individual shutter control, then forced draught is a necessary choice. If for some reason the design exit air temperature exceeds 200°F it is better to keep the fans and drives in the cool air below the forced-draught unit (Fig. 3).

Next some remarks on the number and size of fans. The first guiding principle is to choose two fans in preference to one and the other is to have the fans as large as possible, although some clients do limit the diameter to 12 feet. It is economic to join two tube bundles to form a unit, say 16 ft wide, and to have two fans of 11 ft or 12 ft diameter cooling this unit.

The width of a tube bundle is determined by its service; it may be as little as 1 ft; and by transport considerations which limit it to 8 ft or a little more in special cases. The length is also a transport factor, but it is easy to show that the most economical tube bundle is 30 ft long. The depth, of course, is governed by the number of rows of tubes on triangular pitch, with a maximum of 8 rows in one bundle. Two or more bundles may be stacked, one above the other, for handling viscous fluids. The location and facing of inlet and outlet nozzles should be chosen to give clear access to the headers and so that the movement of shutters, if they are fitted, is not impeded (Fig. 4).

Header Types

Another alternative open to specification in the tube bundle is cover-plate headers as opposed to the more normal plug-type headers. Tube plugs are a most convenient device: they provide all the access that is required for fixing, cleaning or tightening-up the tubes. To those who have doubts on the security of plug-type headers it may be remarked that the author's company, alone, has provided equipment for hydrogen-rich services since 1954 amounting to nineteen different installations with operating pressures ranging up to 4700 psi and inlet temperatures up to 550°F. These installations are all operating satisfactorily. On the other hand, cover-plates are heavy and inconvenient but they may be necessary for extremely difficult fouling conditions. They are usually specified if the fouling factor is 0.004 or over. A confined gasket and stud-bolt fixing should be specified.

Any type of drive may be applied to the fans of air coolers but, in fact, electric motors are most common with steam turbines encountered occasionally. To keep the fan tip speed to the accepted figure of 12,000 fpm a speed reducer is required. The choice lies between right-angle gearbox and V-belt and pulley types. The V-belt drive is cheaper to install and to operate and it has the advantage

that remote lubrication can be arranged: most specifiers limit it to motors of 20 hp.

The disposition of the mechanical drive requires a choice from several alternatives. There is the opportunity here to match the air coolers to their location on grade or aloft, to specify them economically and to save expensive site construction by avoiding separate foundations for the mechanical part of the equipment. For induced-draught units the drive may be V-belt attached to the fan ring for diameters of fan up to 10 ft. For larger fans the recommended drive is suspended, either gear or V-belt. Thus in either case the complete structure and its mechanism are carried on the support columns. For forced-draught equipment the option is slightly different. Up to 10-ft-diameter fans may have attached V-belt drives on the fan rings of the transition hoods, the limitation being obviously for the length of the belts. V-belt drives may also be ground mounted, serving larger than 10-ft fans. The spiral bevel gearbox-drive may also be ground mounted with a long shaft and a structural steel support for the upper bearing, thus avoiding the more costly alternative of the tall concrete pedestal mounting. Suspended drives, however, are becoming the most popular of all.

Specification of Surface

The finned tubes, of course, constitute a most vital part of an air cooler and comprise some 40 per cent of its total cost. If they are correctly specified in regard to material and wall thickness, the heat exchangers can literally run for years without serious maintenance troubles. Experienced operators tend to prefer their steel tubes sheathed with aluminium or protected with zinc and to have aluminium helical fins $\frac{5}{8}$ in. high by 0·020 in. thick spaced 8 or 9 to the inch. Great variation is possible, however, and a widely-used type has $\frac{1}{2}$-in. fins 0.014 in. thick helically wound 11 to the inch and embedded directly in the steel tube wall. The latter may require protection from the elements on the site until the refinery goes on stream, this protection being a liability of the main contractor.

As the product stream is through the tubes, there is no question of differential corrosion between "shell side" and "tube side" as in a traditional water-cooled exchanger. Attention may thus be concentrated upon the effect of the process stream on the tube metal, and one finds, particularly in petrochemical works, stainless steel of different qualities, Monel, aluminium or Admiralty brass for different services. One point on which no comment is offered is the use of solid-drawn seamless or alternatively electric resistance welded tube as the basic material for finning. The controversy about these alternatives can be carried on in the arena of process exchangers, but preferably not here. Sufficient to say that hundreds of thousands of feet of both are in service in air-cooled heat exchangers and as there is a difference in their price the type must be specified.

At this point we can quote some useful multipliers with which the cost engineer can convert standard units into special cases. The basic figure would be the price of an air cooler 75 psi design pressure, plug-type header, 14 Bwg average wall seamless-steel tubes 24 ft long, unsheathed, with wrapped-on fin and with TEFC motors and V-belt drive.

Design Pressure	Standard Construction	Cover-plate Headers	Tubes and Plugs: Monel Metal	Tubes and Plugs: Stainless Steel 18/8-304	Tubes and Plugs: Stainless Steel 18/8-316
75 psi	1	1.05	2.12	1.57	1.82
150 psi	1.02	1.10			
250 psi	1.04	1.15			
600 psi	1.05	—			
For tubes 20 ft long			× 1.06		
For tubes 30 ft long			× 0.95		
For explosion-proof motors			× 1.10		
For spiral bevel gearbox			× 1.075		
For aluminium-sheathed tubes with extruded fins			× 1.075		
Use the sum of all multipliers					

As a preliminary to examining the methods of control for our air coolers, we should take a look at the scope of their operations. In this context, "approach" means the difference between the design ambient air temperature and the product outlet temperature: the "range" is the drop in temperature sustained by the product stream in passing through the cooler. As the figure chosen for ambient air will have a significant bearing on the size and cost of the equipment, it deserves close attention. Let us imagine that we are making an imaginary turnkey bid for a petroleum refinery to be located right in the centre of England. The meteorological records would show:

Monthly average of daily maximum and minimum temperature	*Month*	*Max*	*Min*
	January	43°F	35°F
	July	71°F	55°F
Extreme temperatures recorded in 1957	January	56°F	19°F
	July	**84°F**	49°F

While for many overseas locations we would seek a record of "Duration/frequency for maximum dry-bulb occurrences", the changeable character of our own climate hardly justifies it in this investigation.

Choice of Ambient Temperature

One method of choosing design ambient is to disregard the thermometer reading for 2 per cent of the hours in the four summer months.[2] Another method is to use a temperature not exceeded for 5 per cent of the hourly records throughout the year. Where such detailed records are not available or for purposes of estimate cannot be studied, there remains the straight deduction method; design ambient being taken as from 10° to 20°F below absolute maximum, according to the location of the plant and the degree of critical operations it contains.[3] In our refinery project we will choose 75°F with the client's agreement that he can cut back in the very few hours each year that this temperature is exceeded.

An adequate approach is necessary if air coolers are to present that nice balance of efficiency and economy that we require from them as tools of process engineering. If 40°F can be generally accepted throughout the refinery (giving product outlet 115°F), then it pays to use only air cooling and to take one or two difficult units of 95°F (or even 90°F) outlet temperature in our stride. If too great a heat load is showing too narrow an approach, then trim cooling must be considered and can indeed be faced with equanimity and without loss of faith in the principle of air cooling. Trim cooling is a special sort of painless water cooling. In the services we have encountered, air cooling takes care of the upper bracket of the product temperature range: when it does this from, say, 300°F down to an arbitrary dividing point of 140°F, it is removing the cause of most shell and tube cooler troubles such as scaling, corrosion and dezincification. The small quantity of cooling water required to deal with the remaining low-grade heat is neither expensive to provide nor operate. And anticipating our next paragraph, it may be added that trim coolers can provide the terminal temperature control in those units where they must be installed.

Following our decision to make our Midland refinery air cooled and to select 75°F as design ambient, two points become quite clearly apparent. The first one is that the climatic conditions will not require our full design fan hp to be used every day, even in July. The second is that we must protect the more viscous streams against operations

in freezing weather and, furthermore, enable such units to be shut down and restarted in such weather, if necessary. All this comes under the heading of control and protection, but as we deal with it, we will find that it carries in its train economy.

Control of Performance

As we list the methods of control we first decide that each unit should have two fans. The electric current to the fans may come from different bus-bars, as a precaution against loss of power. Sometimes an especially vital unit is given a steam turbine drive on one fan to ensure that there will be no loss of coolant. And, of course, two fans give the first opportunity of control when one is switched off. The selection governs the shape of the plot plan of the unit; a rectangle very approximately 2:1; it is admitted that one large fan on a near-square unit is more efficient.

One of the two fans on the unit should have automatic variable-pitch control. A good variable-pitch fan, while running at a tip speed of 12,000 fpm, will accept a signal from instrument air and vary the pitch of its four blades over a range of 30 degrees. It should be specified to be "fail-safe" so that the blades naturally move to coarse pitch and deliver maximum coolant on a failure of the control signal. Such a fan will maintain temperature or pressure to very acceptable limits and will accordingly fulfil its first function. However, it offers, in our opinion, the most certain means of achieving maximum fine control and, at the same time, maximum economy.

Remembering that the refinery was designed for ambient air at 75°F, we expect some economies during the remaining 94 per cent of the year when the dry-bulb temperature is below that figure. In fact, when the feathering of auto-variable fan blades has reduced their power demand by 50 per cent, the cooling air delivery has only been reduced by 20 per cent. When the fan hp is down to a quarter of the design hp, there remains, assisted by natural convection, a cooling effect of about 35 per cent. The economy is not hard to find (Fig. 5).

In really cold weather another feature of the variable-pitch fan is brought into play. A pitch range of 30 degrees has been mentioned as being the variation in blade angle within the control powers of the diaphragm in the patent hub. The positive blade angle for normal operation is from 15 to 18 degrees and the blades are set in this region so that the design fan hp is absorbed. Progressively feathering on the air signal from the controller brings the blades to neutral, and they then move into negative pitch and start operating against natural convection of the tube bundle. In freezing weather the fans at a negative pitch of 8 or 10 degrees will retain the heat and insure against the risk of asphaltic or waxy streams stopping up the tubes.

It is for these last-mentioned services that steam coils are fitted. Comprising a single-row bundle of finned tubes fitted below the unit, the steam coil is not very correctly named. Nor is it, strictly speaking, a control device. It is intended for use at start-up times and on other occasions to get the product stream moving through the tubes. There are probably not more than two or three such difficult services throughout the refinery.

Shutters or louvres are fitted both for control and for protection. The first-named function is usually carried out on the top of a forced-draught unit which comprises several small grouped services cooled by one fan or pair of fans: the separate tube bundles have their separate louvres operated by pneumatic actuators and are thus independently controlled. For protective purposes shutters are invariably fitted in association with steam coils and often in cold climates they will be fitted over other units as well: manual operation is adequate in these cases. Two-speed motors are sometimes used on fan drives. They can indeed operate to

Fig. 2. Induced-draught-type transition hoods fitted over tube bundle.

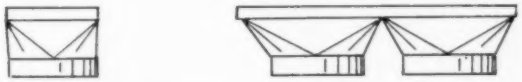


Fig. 3a. Forced-draught-type transition hoods fitted below tube bundle.

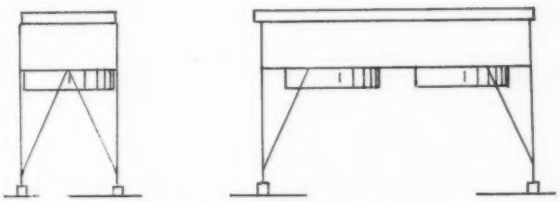


Fig. 3b. Forced-draught-type heat exchanger panel-type plenum chamber.

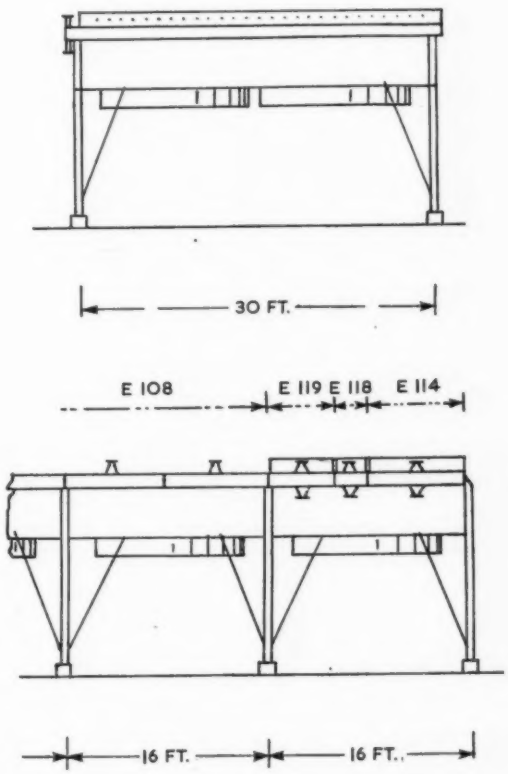


Fig. 4. Arrangement of exchanger connections:
E108: six bundles, three pairs of fans.
E114, E118, E119: combined in one unit with two 12 ft diam. fans and independent louvre control.

save power, but for control purposes they require the assistance of air-actuated louvres. We must remember that these need 100 lb air for their operation, not 15 lb air like the auto-variable fans: consequently, their use on a fairly large scale becomes debatable.

Costs of Equipment

The cost of these various devices for control can be summarized at this point, assuming a two-bundle unit 16 ft by 30 ft with only standard equipment. These items will be additional.

One auto-variable fan 12ft diameter, say ...	£200
Two 8 ft by 30 ft louvres, say	£600
Two pneumatic actuators, say	£180
Two 8 ft by 30 ft steam coils, say	£1400

The additional cost of speed control on electric motors is an item for the main contractor, who is normally responsible for procurement of switchgear. Similarly, the recorder/controllers and the air impulse system are usually taken along with instrumentation.

One last item of protection is the vibration switch. This is the simple and cheap mercury tube device and a useful insurance against damage in the event of a fan drive running unevenly.

To complete the picture of air-cooled exchangers are the ladders and gangways which are optional items on units constructed on ground level. There it is possible to attend to mechanical drive maintenance with portable equipment or to erect scaffolding for work at the headers.

When it comes to units mounted high over pipe tracks, the majority view is that access gangways are well worth while and that they should be fitted along both headers and have spurs for servicing the mechanical drives. Easy access means good maintenance. Ladders and gangways, therefore, should be an item not forgotten in the estimates.

Information Required by Contractor

Now let us examine the essential information to be provided by the main contractor so that vendors can submit well-calculated offers for air cooler equipment. Until recently there was a lot of individualism about specification data sheets: everybody used a different layout and confusion and error were liable to arise. Now a very sensible and straightforward specification sheet has been standardized by the Air Cooled Exchanger Manufacturers Association. Common to all the services in the refinery will be:

Air Side Data: Design ambient air temperature.
Altitude.

A separate air cooler data sheet will provide, for each separate product stream:

Tube Side Data: To comprise the fullest possible information on the liquid or vapour, including condensing curves, where applicable.
Fouling factor.
Allowable pressure drop.
Preferred grouping of units together or in banks of coolers. If at grade level.

Construction Data: Preference for induced or forced draught, if any. Tubes, seamless or E.R.W.
Average wall or minimum wall; also preferred material, gauge and type of finning.
Headers, preferred material and corrosion allowance.
Plug-type or cover-plate type.
Size of nozzles.
If gangways and ladders required.

Mechanical Drive: Type of driver.
Type of speed reducer.
Instructions about control devices.

The most essential item of the enquiry has still to be described: it is a statement whether the tender is required only for budgetary purposes, or for an estimate or against a firm contract. To forestall any unjustified difference of opinion on this situation, it is necessary to point out that the proper rating, selection and tabulation of one process stream alone may take an experienced mathematician one and a half days. The calculation sheet for a finished condenser will contain more than 1200 figures because this type of work includes "consideration and rejection" or, as some may put it, "trial and error", it can be imagined that the working-out sheets carried many more. For the air coolers and condensers in a complete 20,000-bpd refinery there are exactly 40 specification sheets and they represent the work of three men for two and a half weeks.

One cannot expect to get this sort of thing for a budget enquiry. Most firms would like to give it for every estimating estimate, but there isn't time, especially if it is a "turn-key" bid and each of four or five firms tendering comes up with a different refinery plan to produce the specified end products. This accurate rating and careful selection of units and their assembly in economic groups will be the basis of a quotation which any reputable manufacturer of air coolers will expect to provide against a contract tender. That is, to the main contractor who has got his contract. We hope that the ultimate client, the oil company, and the immediate customer, the main consultant/contractor, do realize that estimating estimates, which must of necessity be taken from curves, are not a proper basis for building an oil refinery. In our experience the air-cooled heat exchangers have never yet held up the inauguration of a new plant; they do deserve a three-week period of investigation at the commencement of the job.

The basic information required by the consultant/contractor at the estimating stage comes under four headings: plot plan, fan driver hp, shipping weight and price. This will readily be furnished by the air cooler manufacturer from curves which embody his accumulated experience; and will be submitted in the form of a summary. Two completed lines from such a summary are shown:

The missing column in this tabulation, of course, is price. When the prices of all the units are totalled up, you have the cost of the air coolers for the refinery except for shipping charges and erection costs. These are both a normal responsibility of the main contractor, but we are often asked for guidance: the overall cubage of crated Solo-Aire equipment runs at an average of 100 cubic feet per long ton net

Item	No. and Size of Bundles	No., Size and Type of Unit	Bare Tube Surface	Motors No. and hp	Plot Area	Approx. Weight
Atmospheric Tower Overhead Condenser E.108	(6) 8–303	(3) 16–303	5480	(6) 20	48 ft × 30 ft	83,000
Splitter Bottoms Cooler E.114			1190			
Stabilizer Bottoms Cooler E.118			346			
Stabilizer Overhead Condenser E.119			814			
E.114	(1) 8–304					
E.118	(1) 2.5–304	(1) 16–304		(2) 20	16 ft × 30 ft	40,000
E.119	(1) 5.5–304					

weight of the air coolers. As regards erection on site, we are led to understand that 7 per cent of our quoted price is found to cover all erection costs, with the exception of pipe manifold and electrical connections.

Evaluation of Tenders

The evaluation of tenders is a subject bristling with difficulties. A marked tendency for the purchaser to reserve to himself the supply of electric motors does not help to clarify the issue, as will be evident when we look into it. For our study of comparative evaluation we are fortunate in having available an authoritative three-way analysis[4] of a condenser/cooler with a heat load of 31.5 MMBTU/hr.

Selection	*A*	*B*	*C*
Finned surface, sq ft	12,360	14,735	16,425
Plot area	2,520	2,940	4,320
Fan horsepower	221	118	72
Price (including motors)	£30,400	£34,000	£41,400

We will record that the purchaser specified evaluation to allow for 8000 hours' running per annum (330 days), that the installed capital cost of the electric power supply was £15 per kW and that running cost of power was 1d per kWh. Then, for the purposes of our calculation:

	A	*B*	*C*
kW (= hp × 0.746)	164.5	88	53.7
Fixed offsite power investment (kW × £15)	£2470	£1320	£806
Operating cost per annum (kW × 8000 × 1/240)	£5480	£2940	£1790

If the purchaser specifies that the pay-out period is to be 2½ years			
	A	*B*	*C*
Quoted price	£30,400	£34,000	£41,400
Power investment	2,470	1,320	806
Operating power cost	13,700	7,350	4,470
	£46,570	£42,670	£46,676
If the purchaser prefers a pay-out period of 5 years			
	A	*B*	*C*
Quoted price	£30,400	£34,000	£41,400
Power investment	2,470	1,320	806
Operating power cost	27,400	14,700	8,950
	£50,270	£50,020	£51,156

These figures show that properly designed air coolers will strike the happy medium between first cost and operating cost. This would have been less evident if electric motors had been excluded from the vendor's price.

To the comment that tax liabilities have been here omitted and that many jobs come to tender without any mention of these factors at all, our reply would be that the rating engineer who made his selection Column B probably did so initially without thinking of cost factors but by aiming, as usual, at a soundly balanced engineering job. A final check with pay-out factors would ensure that there was nothing unusual to unbalance the figures.

Pressure drop, particularly early on, will be fairly conservatively fixed. Possibly an air cooler maker will try to select a rather low surface area and more passes, with higher mass velocity, all at the expense of pressure drop. The purchaser should have his own figures given a final "vetting" in case the "allowables" may be increased: then vendors should be penalized by the addition to their price of 3 per cent to 10 per cent for pressure drop increment 20 per cent to 50 per cent above specification.

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[2] Thomas, J. W., Standard Oil Co., Ohio, *Petroleum Refiner*, April 1959.
[3] Collins, G. F., and Mathews, R. T., Du Pont de Nemours Co., A.S.M.E., 59-A-255.
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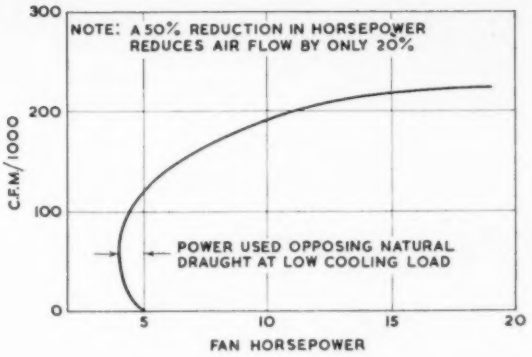

Fig. 5. Horse power vs. air delivery curve for a 14 ft diam. Auto-variable fan, four blades, 272 rpm.

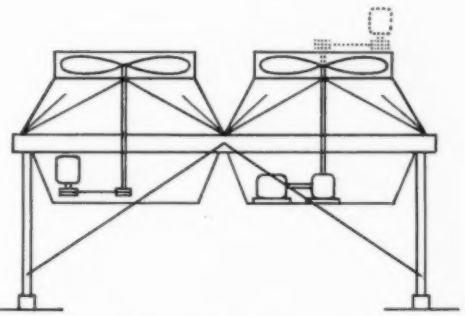

Fig. 6. Various induced-draught fan drive arrangements are possible, such as: (bottom) suspended drives, V-belt on left, gearbox on right; (top dotted) an attached V-belt drive.

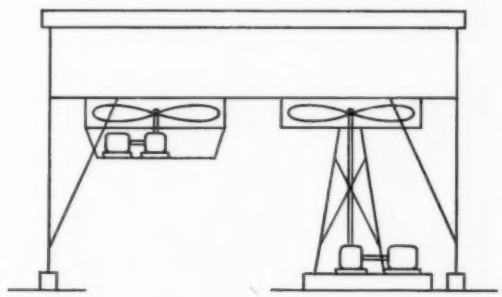

Fig. 7. Forced-draught fan drives two-drive arrangement with motors coupled to gearboxes.

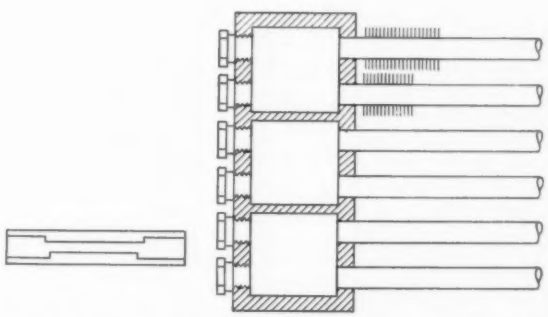

Fig. 8. Tube bundle header arrangement for a bundle with six rows and four passes.

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PART I

THE STATUS AND REMUNERATION OF THE PROFESSIONAL MAN IN INDUSTRY

It is shown that professional employees receive remuneration according to definite remuneration laws and according to National Remuneration Scales. Remuneration of engineers, chemists and manual employees is analysed and compared. Status (a measure of "differential") and other measures are defined to enable professional individuals and groups to be compared with other individuals and groups. The chemist is better off than the engineer and the more successful professional employee is losing ground when compared with his less successful colleagues.

by M. DAVIDMANN

Introduction

THE Royal Institute of Chemistry surveyed the earnings of its corporate members in 1953,[1] 1956[2] and in 1959.[4] A survey of the earnings of members of the Institutions of Civil, Mechanical and Electrical Engineers was carried out, for the income tax year 1955/56, by the Social Survey Division of the Central Office of Information.[5, 8] The two surveys were compared,[7] it being concluded that chemists during 1956 earned appreciably more than the engineers concerned, and that the earnings of chemists advanced markedly between 1956 and 1959. A list of starting salaries for chemical engineers has been published.[6] Income surveys have also been carried out in the United States.[12, 13, 14]

Chemical engineers are included in the Engineers' Guild latest survey, the results of which should be available by January, 1961. As regards engineers, some idea of relative numbers is given by the total membership figures,[3] both corporate and non-corporate, of the professional institutions for 1959:

Institution of Civil Engineers	24,100
Institution of Mechanical Engineers ...	50,100
Institution of Electrical Engineers ...	44,500
Institution of Chemical Engineers ...	4,300

Surveys such as those carried out in the United Kingdom, based on membership of a professional institution, do not include those employees who do equivalent work but do not have professional qualifications in terms of corporate membership of an appropriate institution. Such employees are common in engineering, but non-existent in medicine. In addition, not every professionally qualified person practises the profession in which he originally qualified.

The remuneration of a professional employee increases with age, up to a point. But a salary is paid not in accordance with age-group, but according to the work done. This is the common factor which links the professions amongst themselves and to other members of the society, such as, for example, manual employees.

Remuneration surveys are examined here and interpreted so that individuals, grades within the professions and groups of people who receive remuneration for doing the same type of work can be compared. Individuals may compare their own progress as regards remuneration and status with that of others within their own grade or group. Changes in status between individuals in different grades or groups may similarly be evaluated. For example, the status of the professional employee is changing relative to that of the manual employee and this change is evaluated in the article. Groups may be compared with each other, for example, one profession with another or with a group of manual employees.

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Remuneration Surveys

The data in these surveys is obtained from questionnaires duly completed by a considerable percentage of the members of the group. The sample size is chosen so that the survey is representative. The sample is divided according to age groups and for each age group the data consists of an income distribution. The corresponding cumulative frequency distribution can be drawn, so that for any given cumulative frequency we have the corresponding income. The cumulative frequency is termed the "fraction"; the corresponding income is termed the "quantile". The quantile gives the limiting income for its fraction. In other words, this fraction of the sample, for the particular age group being considered, has an income which equals, or is less than, its quantile. The quantiles commonly used in remuneration surveys are the deciles, octiles, quartiles and the median, as follows:

Fraction %	*Quantile*
10, 20, ... 90	deciles
12½, 37½, 62½, 87½	octiles
25, 75	quartiles
50	median

Quantiles corresponding to particular fractions are determined for each age group, tabulated and illustrated by graphs of income plotted against age. These graphs illustrate the income distribution for the sample, and thus for the whole group which the sample represents.

Income distributions differ markedly between professions. Hence they have been compared[8] by means of "career earnings" from age 30 to age 65. Career earnings represent the earnings of a man in a particular profession, aged 30 at the time of the survey, between the ages 30 and 65, working full-time, all circumstances remaining unchanged

from the year of the survey. Average incomes were used in compiling career earnings and attention was drawn[8] to a possible disadvantage of this method: "The average does not indicate whether the earnings of most members of the profession are close to that amount, or whether a few earn a great deal more and a good many much less."

Here we analyse further the data available for professional chemists[1, 2, 4] and for professional civil, mechanical and electrical engineers[5, 8] as a group.

Analysis of Remuneration Surveys

The income earned in any particular year by a given fraction of the population correlates as a function of age, as follows:

$$Y_r = y_{0r}e^{-(X_r - x_{0r})^2/b} \quad \ldots . (1)$$

where Y = income, usually the gross earned income (£ p.a.);
X = age;
x_0 = age at which Y is a maximum;
y_0 = maximum value of Y, at $X = x_0$;
b = constant;
r = suffix, indicates that the levels are those pertaining to the year "r" to which the survey refers.

When G represents the fraction, in per cent, then the income distribution for the group as a whole, or for any part of it, is completely defined by

(a) the level of the constant b;
(b) the relation between x_{0r} and G;
(c) the relation between y_{0r} and G.

The income distribution of chemists and engineers has been analysed accordingly. The results of the calculations are given in Table I.

The data in Table I are illustrated by Figs. 1-4. Figs. 1 and 2 illustrate the x_{0r} and y_{0r} distributions for chemists, Figs. 3 and 4 those for engineers. It is seen that the chemists' x_{0r} distribution has not changed appreciably between 1953 and 1959, and neither has the level of b. Taking values of x_{0r} and y_{0r} from Table I, but values for x_{0r} for chemists from the single curve in Fig. 1, and taking $b = 1985$ for engineers and $b = 1265$ for chemists (see Table I), we can then compare the original data with the derived equations. The comparison is illustrated by Figs. 5-8, and reasonable correlation is obtained.

TABLE I.—Analysis of Remuneration Surveys for Engineers and Chemists

Fraction	Age at which Income is a Maximum	Maximum Income
G	x_{0r}	y_{0r}
%	years	£ p.a.
Chemists—1953		
50	57.3	1483
Chemists—1956		
25	53.4	1366
50	57.0	1811
75	61.2	2574
Chemists—1959		
12½	51.9	1418
25	53.5	1627
37½	55.7	1877
50	57.0	2126
62½	58.5	2441
75	60.7	2933
87½	65.6	4178
Engineers—1955/56		
25	56.9	1187
50	62.8	1615
75	72.1	2626
90	79.6	4453

Note: b is 1985 for engineers and 1265 for chemists.

Symbols Used

b = constant, defining the distribution of remuneration with age, for a particular group or subgroup;
i = rate of change, per cent compound rate of change per year, generally expressed as a fraction;
x_0 = age at which remuneration is a maximum, for a particular grade;
y_0 = maximum level of remuneration, at age x_0;
C = career or mean career earnings (£);
E = remuneration received by manual employee during one year, preferably the fiscal year (£);
G = fraction (per cent) = grade. For example, $G75$ = grade 75 per cent when fraction = 75 per cent.
I = index, preferably used on the basis that $I = 1$ in the reference year.
S = status, that is remuneration ratio;
S_{12} = status, ratio of remuneration of subject "1" to subject "2", with S_{12} preferably $\geqq 1$.
T = time, that is year, for example: 1960. Either fiscal or calendar year, preferably fiscal year;
X = age (years);
Y = remuneration received by professional employee during one year, preferably the fiscal year (£).

Suffixes

g = grade;
m = manual employee;
n = any particular year;
p = professional employee;
r = reference year, for example year to which survey refers or in which a particular index is 1;
s = status;
R = reference year of economic index;
X = at constant age.

Further, from Equation (1), it is seen that:

$$Y_r/y_{0r} = e^{-(X_r - x_{0r})^2/b} \quad \ldots . (4)$$

The constant b thus defines the income distribution, for any particular group, and this can be illustrated by a graph of Y_r/y_{0r} versus $(X_r - x_{0r})$. All the data can be plotted and compared with the income distribution as calculated by Equation (4). Figs. 9 and 10 illustrate the degree to which the estimated constants correlate the data, for chemists and engineers, respectively, x_{0r} and y_{0r} having been determined from Table I and Fig. 1, as before.

The National Remuneration Scale

The constant b and the x_{0r} and y_{0r} distributions having been determined, we may now draw up the National Remuneration Scale for each profession.

The national scales for chemists and engineers are given in Figs. 11 and 12 for the years 1959 and the Income Tax year 1955/56 respectively. The scale consists of the decile earnings. The scales are static, applying to a particular year. The evidence on the chemists' income distribution shows that one may expect such scales to alter with time only as regards the y_{0r} distribution. The chemists' income distribution remained virtually constant over six years, apart from the y_{0r} distribution. It may reasonably be assumed that this applies generally, although there are known exceptions.

The national remuneration scales given here were calculated from the x_{0r} and y_{0r} distributions, the constant b having been determined already. They could have been determined from the cumulative income distribution for each of the age groups, the distribution constant b and the x_{0r} and y_{0r} distributions being also determined from the decile

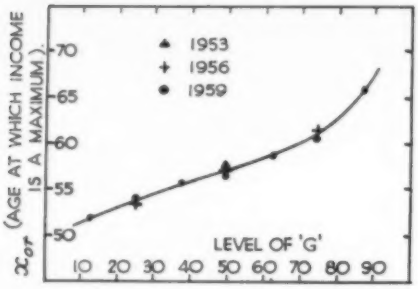

Fig. 1. Distribution of age at which income is a maximum for chemists.

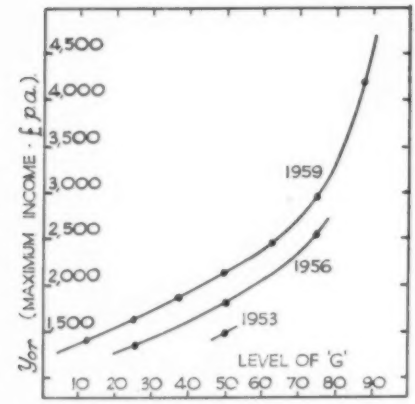

Fig. 2. Distribution of maximum income for chemists.

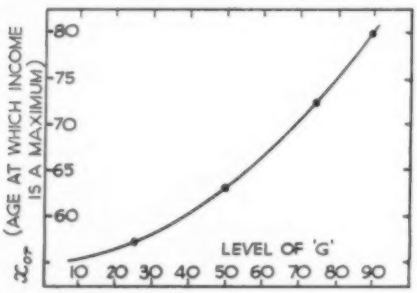

Fig. 3. Distribution of age at which income is a maximum for engineers (1955/56).

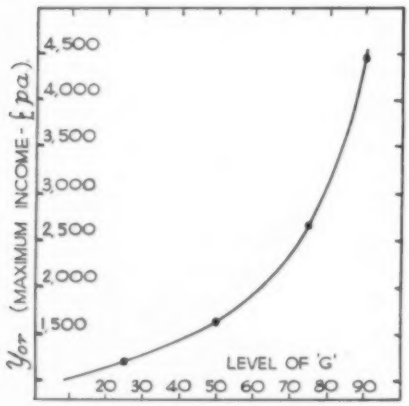

Fig. 4. Distribution of maximum income for engineers (1955/56).

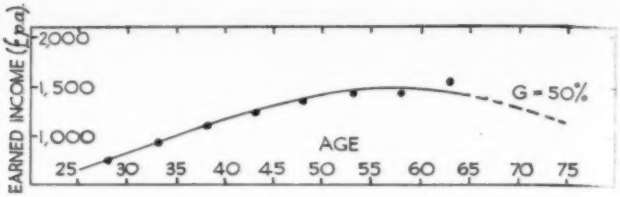

Fig. 5. Remuneration of professional chemists (1953).

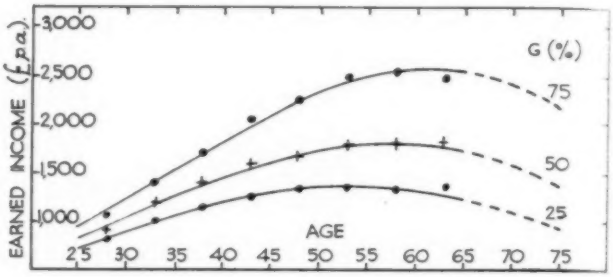

Fig. 6. Remuneration of professional chemists (1956).

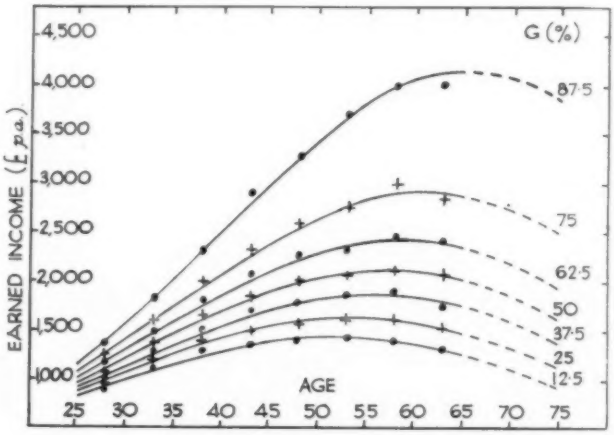

Fig. 7. Remuneration of professional chemists (1959).

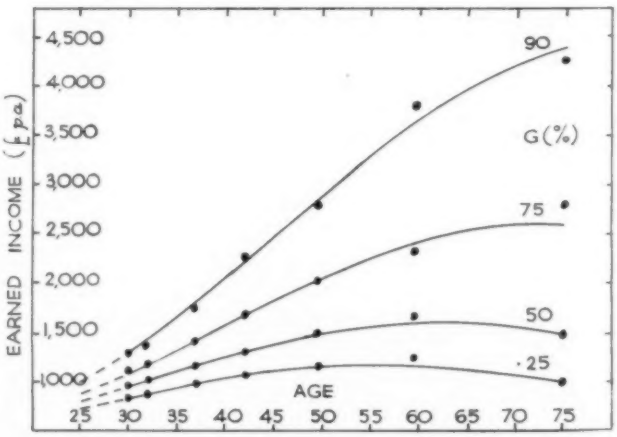

Fig. 8. Remuneration of professional engineers (1955/56).

income distributions. There is a strong case for future surveys to be recorded in this way.

Criteria of Comparison and the Measurement of Change

By "grade" is meant the position of an individual relative to other individuals within the group. Grade is defined by the "fraction" and, for example, an individual of grade 20, this being denoted by $G = 20$ or $G20$, receives remuneration such that 20 per cent of individuals in his own group receive the same remuneration or less. Individuals of the same grade form a sub-group within the main group, and the term "grade" applies to the individual as well as to the sub-group.

For the Individual

An individual, on entering up his age and remuneration in the appropriate scale, for the year to which it applies, may now estimate his grade by estimating G by interpolation.

The individual's grade measures his status within his group and the value of G enables him to compare his progress with that of others. If the value of G rises, his status rises. If G is lowered, his status within his group is lowered.

For the Grade

The measure adopted for comparing different grades, within the same group, is termed the "career earnings", from 30 to 65 years of age. This has already been defined[3] for a group, on the basis of average income per age group. It is here defined as representing what an individual of a particular group may earn if he worked on a full-time basis from age 30 until age 65, should he remain in his grade throughout this period, and should the remuneration scale remain constant in all respects.

Career earnings may be calculated for any particular grade from the national remuneration scale (Figs. 11 and 12). When interpolation is not considered to be sufficiently accurate, the remuneration for any particular grade may be calculated from Equation (1) when the value of b and the x_{0r} and y_{0r} distributions are known.

Career earnings were calculated from the national remuneration scales and Table II lists the results, which are further illustrated by Figs. 13 and 14.

The changing level of y_{0r} is a measure of how grades advance in relation to each other, within a group. Considering the data for chemists (Fig. 13), we see how the relative position of grades, that is, their status, is changing. Fig. 15 illustrates this point, the gross earned income of the lower grades increasing at a faster rate than that of the higher grades. Over an interval of three years, between 1956 and 1959, the gross earned income of the $G25$, $G50$ and $G75$ grades increased by 19 per cent, 17 per cent and 14 per cent respectively. A process of equalization appears to be taking place, the more successful chemists losing ground to their less successful colleagues. To that extent the status of the more successful relative to the less successful chemist is being reduced. It is this status which provides incentive

TABLE II—Career Earnings

Grade	Chemists				Engineers
G (%)	1953	1955 (estimated)	1956	1959	1955 56
10	—	—	—	43,900	—
20	—	38,300	—	49,000	36,100
25	—	40,200	43,200	51,300	—
30	—	42,400	—	54,000	40,000
40	—	46,700	—	59,100	44,000
50	45,100	51,500	55,100	64,500	48,300
60	—	57,400	—	71,000	53,600
70	—	65,000	—	78,900	61,800
75	—	69,700	73,700	83,800	—
80	—	77,800	—	92,500	73,300
90	—	—	—	114,800	92,900

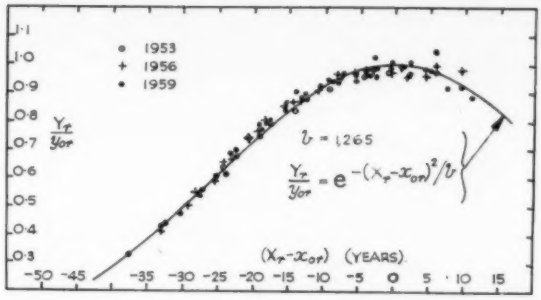

Fig. 9. Income distribution for chemists.

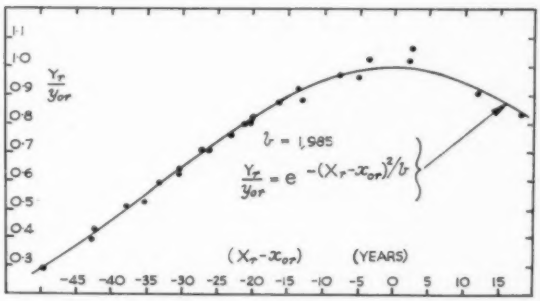

Fig. 10. Income distribution for engineers (1955/56).

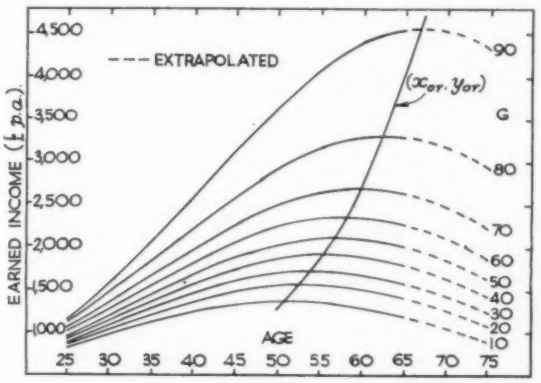

Fig. 11. National remuneration scale for professional chemists (1959).

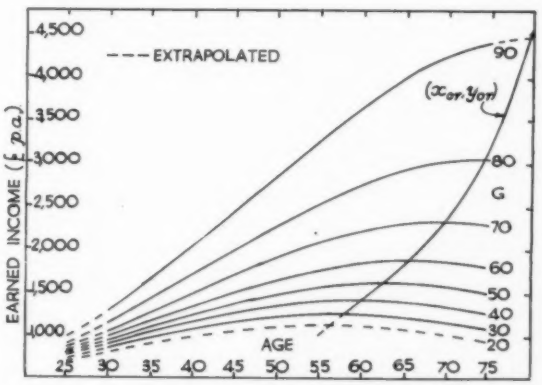

Fig. 12. National remuneration scale for professional engineers (1955/56).

to succeed and it is incentive for producing outstanding work which is being reduced.

Status is relative position, and may be evaluated as a career earnings or mean career earnings ratio, for grades or groups, respectively. For example, the status between the $G75$ and $G25$ chemists was 1.71 in 1956 and 1.63 in 1959.

For the Group

To compare different groups with each other the measure "mean career earnings" is used. This is the mean earned income of the middle 60 per cent of the group, that is, that part of the group which falls between the limiting grades $G20$ and $G80$. It is the mean ordinate of the career earnings distribution (Figs. 13 and 14) between the limits $G20$ and $G80$. It reflects changes in the level of remuneration and differences in incentive to advance to higher grades within one's own group, for the middle section of the group, and thus prevents outstanding success or failure of small sections of the group from affecting the comparison.

Mean career earnings for chemists and engineers are given in Table III.

Table III gives the comparative data on chemists and engineers. It is seen that chemists occupy a position of higher status within the community when compared with engineers. Changes in status, with time, can be assessed, as already illustrated for grades. The status of chemists as compared with engineers was 1.03 in 1955.

Chemists and Engineers

The remuneration of chemists and engineers is compared in Figs. 16-18. Fig. 16 compares the basic earned income distributions; Figs. 17 and 18 compare the x_{0r} and career earning distributions, respectively, grade for grade. It is seen that the earned income of chemists increases more rapidly with age than does that of engineers (Fig. 16) and that the chemist reaches his maximum income at an earlier age than the engineer (Fig. 17), grade for grade. This difference is appreciable for the higher grades.

TABLE III—Mean Career Earnings

Year	Mean Career Earnings	
	Chemists	Engineers
	(£)	(£)
1955	53,400*	50,400†
1956	56,700	
1959	66,000	

Notes: (1) * Estimated.
(2) † 1955/56.
(3) Limits of G: 20 to 80 per cent.
(4) Limits of X_r: 30 to 65 years of age.

The chemists' career earnings were estimated for the year 1955 on the assumption that the pattern of change between grades (Fig. 15, 1956-1959) would apply to the period 1955-1956, this pattern being superimposed on the overall change. The estimate is given in Table II and is compared with the original data by Fig. 13.

The mean career earnings are given in Table III.

The chemists' 1956 survey is based on salary payable on April 1, 1956. The Engineers' survey analysed income during the fiscal year 1955/56. Hence a direct comparison would have been weighted. Given an increase in salary during the fiscal year, the salary (rate of earning) at the end of the fiscal year would be higher than earnings received during the fiscal year. By estimating the chemists' data for April 1, 1955, from that on April 1, 1956, weighting is reversed. The chemists' income is now likely to be underestimated and this, although reducing the reliability of the calculated ratio between chemists and engineers, supports the conclusion that chemists then had a higher status within the community when compared with engineers.

We may summarize the comparison between chemists and engineers as follows:

(1) We are comparing professional chemists, as a group, with professional civil, mechanical and electrical engineers, as a group, in the fiscal year 1955/56.
(2) The chemist's income increases more quickly with age, grade for grade, than that of the engineer. The chemist reaches his maximum income at an earlier age. On the whole, the chemist's income distribution is the more desirable, as earnings increase with need to a greater extent than that of the engineer.
(3) The chemist's mean career earnings are greater than those of the engineer. They each have the same incentive to advance to a higher grade, grade for grade (Fig. 18). This incentive, for chemists, was reduced during the period 1956 to 1959, no data on this point being available for engineers at the time of writing.
(4) Chemical engineers are not included in this comparison. It should be noted that the earnings of chemical engineers appear to be higher than those of other engineers, when both are employed by chemical plant contractors.

Other Professions and Manual Employees

Extensive data for other professions was published in the Report of the Royal Commission on Doctors' and Dentists' Remuneration.[8] To illustrate further the method, and to extend the comparison, the distribution of career earnings (Table IV, Fig. 19) and the mean career earnings (Table V) were calculated for a few of the professions, by the method given in the Report,[8] but for each grade. It is seen that, compared with the chemist and the engineer, the university teacher earns more, but has somewhat less incentive to advance within his group, particularly at the higher grades. The general medical practitioner and the general dental practitioner earn more than any of the other professions. Over the greater part of the range considered, the incentive to succeed (that is, the reward for success) is greater for the general medical practitioner than for any of the other professions, and greater still for general dental practitioners. Up to grade $G55$ the medical practitioner earns more than the dental practitioner. Beyond this grade, the successful dental practitioner earns more than the successful medical practitioner. The very successful dental practitioner earns much more than the very successful medical practitioner. On the other hand, general medical practitioners form but part of their profession, which includes consultants, who may be regarded[8] generally as the

TABLE IV—Career Earnings (£) of Selected Professions (1955 56)

Profession*	Grade G (%)			
	25	50	75	90
General medical practitioners	58,400	76,800	94,400	110,800
General dental practitioners	54,700	75,500	102,700	137,800
University teachers	49,200	60,500	74,300	88,500

* Each profession is defined in the Report of the Royal Commission.[8]

TABLE V—Mean Career Earnings and Status (1955/56)

Profession	Mean Career Earnings		Status of Professional Relative to Manual Employee
	As given by Royal Commission*	As calculated here	
General dental practitioners	79,000	77,200	4.52
General medical practitioners	79,000	76,600	4.48
University teachers	63,000	61,100	3.58
Chemists	—	53,400	3.13
Engineers	59,000	50,400	2.95
Manual employees	—	17,100	1.00

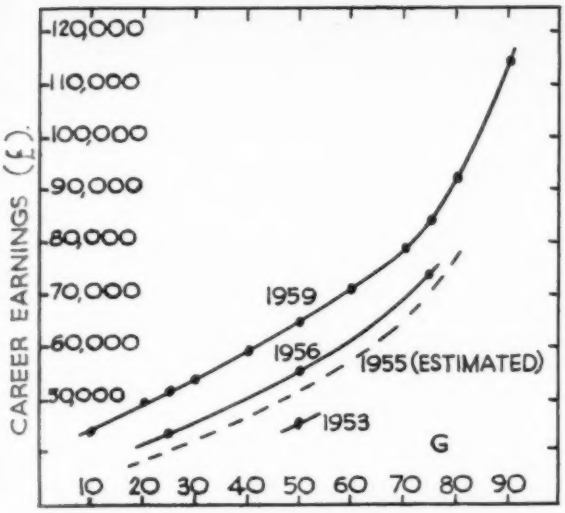

Fig. 13. Distribution of career earnings for chemists.

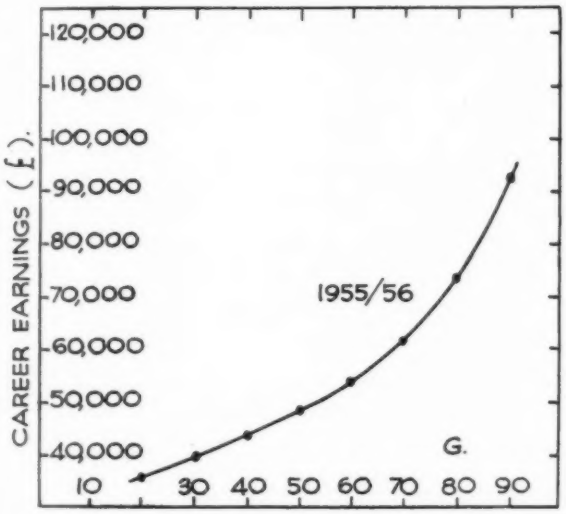

Fig. 14. Distribution of career earnings for engineers.

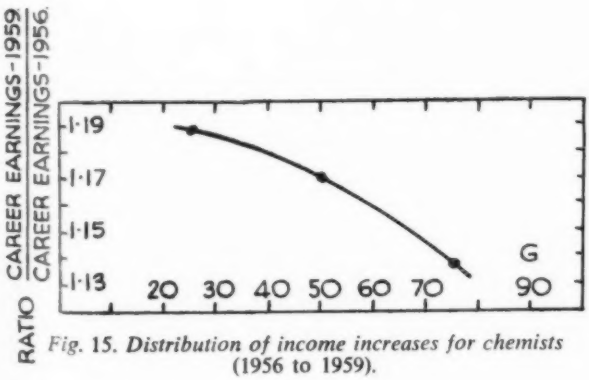

Fig. 15. Distribution of income increases for chemists (1956 to 1959).

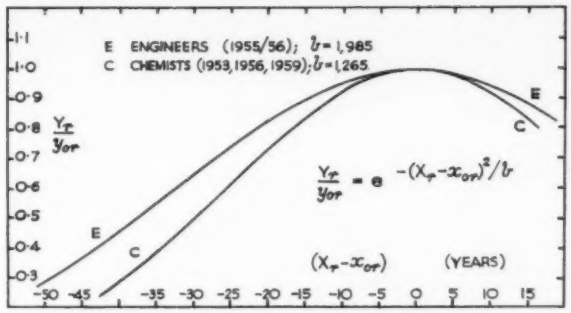

Fig. 16. Comparison between income distributions of chemists and engineers.

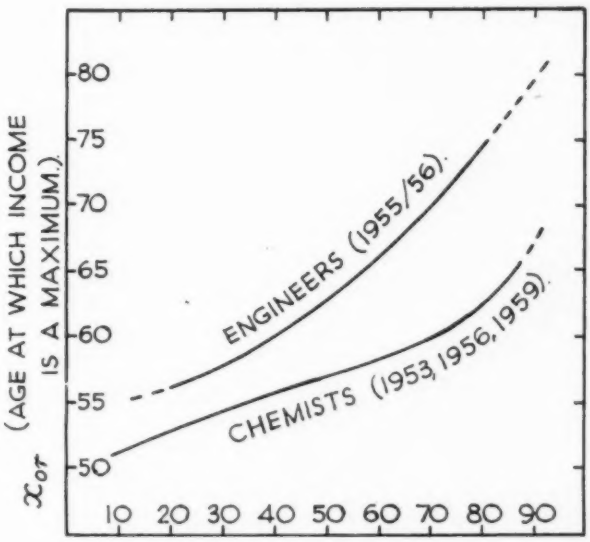

Fig. 17. Distribution of age at which income is a maximum for engineers and chemists.

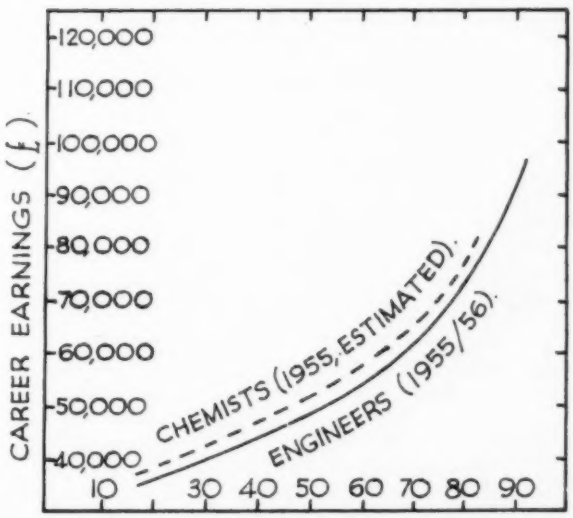

Fig. 18. Comparison between the career earnings distributions of engineers and chemists.

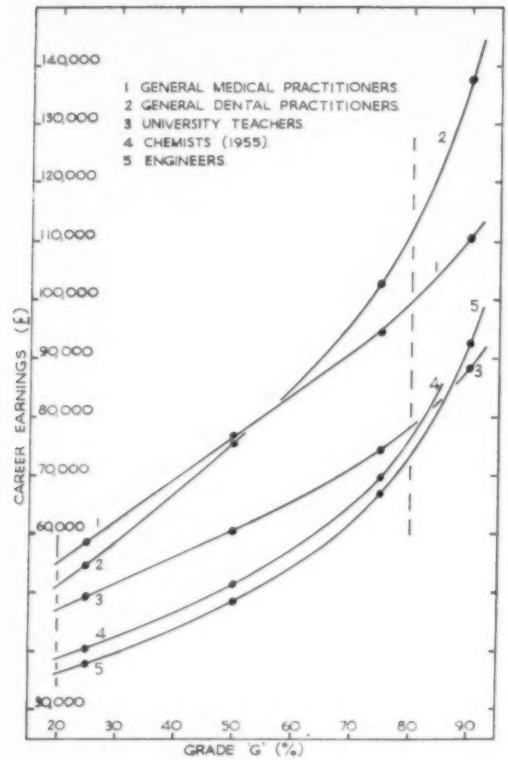

Fig. 19. *Career earnings distributions* (1955/56).

more successful part of the same profession.

For the medical profession, including consultants as well as general medical practitioners, the level of income and incentive would be higher than for the general medical practitioner and any conclusion regarding the medical profession should be based on combined data for consultants and general medical practitioners.

Chemists and engineers do not, on the whole, compare well with university teachers, but the outstanding (*G*85) engineer or chemist earns as much as the equally outstanding university teacher. Quite apart from level of remuneration, most (up to about *G*65) engineers, chemists and university teachers have far less incentive to succeed (that is, to do outstanding work) than the general dental and medical practitioners. And such incentive as is there appears to be in process of still further reduction.

The mean career earnings are listed in Table V, which compares those calculated here with those given in the Report of the Royal Commission[8] which were based on average incomes per age group. The mean career earnings here calculated are lower, particularly for engineers, as they are not influenced to the same extent by the relatively high remuneration of the few highly successful practitioners.

The ratio between mean career earnings is a measure of status. The mean career earnings for a manual employee may be estimated also. For example, the average weekly earnings of all operatives in all industries in October 1955 was £9 7s 2d per week.[9] Assuming that his income is, therefore, about £487 p.a., his career earnings, assuming an effective life of 35 years, which is the same as that of a professional employee, would be about £17,000. Hence we may evaluate the status of professional relative to manual employees for the fiscal year 1955/56. As given in Table V, for example, the status of the engineer compared with that of the manual employee was about 3, the engineer's mean career earnings being about 3 times that of the manual employee.

In arriving at the career earnings of the manual employee, no allowance is made for possible variations in the age distribution of manual employees in different industries or organizations, nor is the ratio of female to male employees considered. Further, the manual employee is fully trained at an earlier age than the professional employee so that a case could be made out for assuming a longer effective life for the manual employee. However, in this article we are concerned with rates of change of status rather than with absolute levels, and in comparing professional with manual employees in general rather than evaluating the position within a particular organization or industry, and it is convenient to choose the same effective life for both manual and professional employees.

(To be continued)

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COMPUTERS FOR THE CHEMICAL ENGINEER

by J. S. M. BOTTERILL

ABOUT 300 attendances were registered at the one-day symposium, "Computers for the Chemical Engineer", held in the University of Birmingham on March 28 last. The programme, touching on all aspects of computers of interest to the chemical engineer, succeeded in attracting professional chemical engineers from many branches of the industry and control engineers were also well represented. Arranged jointly by the Graduate Section of the Birmingham University Chemical Engineering Society and the Midland Graduates and Students Section of the Institution of Chemical Engineers, the meeting was also notable for the general smoothness of its organization.

The first paper by MR. K. A. REDISH, Lecturer in Computing in the University, "Computers and Programming", introduced the background to the application of analogue and digital computers. The rest of the morning session was devoted to management and research applications. MR. D. G. THOMPSON'S contribution, "Plant Management Applications", was illustrated from the experience of the Esso Petroleum Co., Fawley. MR. J. E. RIJNSDORP'S paper on "Computers in Distillation Dynamics Research", based on work at the Koninklijke/Shell Laboratium in Amsterdam, was invited to show how, in a particular research project, analogue and digital methods of computation are complementary. However, this paper also aroused much interest because of its contribution to the general analysis of plate distillation column behaviour. The morning's session was under the chairmanship of MR. J. R. WILLIAMS, Chairman of the Graduate Section of the Birmingham University Chemical Engineering Society.

The afternoon session was devoted to computer control systems. Some may think this gave undue weight to control systems, particularly when so many interesting research applications could have been described supplementing the morning's session. However, the afternoon's papers particularly illustrated how control systems may be expected to develop. How, through the use of more computation if given adequate information, the control loop may assume within itself many aspects generally considered the function of active management. The afternoon's session was introduced by a paper by MR. L. GALLON, formerly leader of the operational research group of B.P. at Sunbury-on-Thames. He reviewed the general field, "The Need for More Process Control Computation". The three following contributions were presented by representatives of manufacturers. MESSRS. R. J. REDDING and F. H. BODLEY in their paper, "Simple Computing Relays", described the Evershed & Vignoles analogue computing device. The analogue computer of De Havilland Aircraft Co. was then described by MESSRS. M. JAMES and W. T. LEE in their paper, "Anatrol —an Analogue On-line Process Control Computer". This and the Ferranti machine described by MR. W. F. M. PAYNE in his paper, "The Argus Digital Computer in Process Control", are machines increasing markedly in order of complexity. However, all these three devices have in common the fact that, in greater or lesser degree, they offer the prospect of "feed-forward control", i.e., such a system that, when the process dynamics are understood, it is possible to adjust the process to compensate for detected entering disturbances. This overcomes the inherent delay in feed-back control systems where it is only possible to initiate correcting action after the disturbance has travelled through the unit and deviation has occurred in the process condition which it is desired to control. MR. J. MCMILLAN, of the I.C.I. Central Instrument Laboratory, chairman of the afternoon's session, in his concluding remarks stressed how feed-forward control was the great step forward in control philosophy, having quite different potentialities from the slower action of a purely feed-back system.

It is expected that the full proceedings of the symposium, including the edited discussion, will be available early in June. This is being published as a supplement to the *Birmingham University Chemical Engineer*.

Computers and Programming

MR. REDISH'S paper discussed aspects of digital and analogue machines. The two-state elements by which the high-speed electronic digital machines operate lead naturally to binary or modified binary codes. Basically, the operations of which the machines are capable are very simple. All depends on observing the state of the two-state elements. Should two that are combined be at the "lower level", the resultant signal is at the "lower level"; if one is at the "higher" and the other at the "lower", the resultant is still at the "lower", whereas if both are at the "higher" the resultant is at the "higher" level. Even to achieve addition the machine must be suitably instructed to observe the condition in one store corresponding to one number and that in another corresponding to the other number and to combine these so as to form the sum. Obviously, more complex operations may then be built up. Multiplication can readily be achieved by successive addition.

The sequences required for common operations are built into the machines. Usually these consist of the simple arithmetic operations: $+$, $-$, $\times$, $\div$. One or two machines can extract square roots without the detailed arithmetic programme being written out by the programmer; some machines are arranged to handle calculations in £, s and d. Also the machines must be able to carry out simple organizational routines (accept information, transfer it from one part of the machine to another according to the pro-

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gramme instructions and then read out the answer at the end of the calculation routine). Finally, the machine must have the capacity to reach simple logical conclusions such as detecting which number is larger than another or proceeding with a given routine until a number is reduced to zero or goes negative and so on.

Generally one of the chief limiting factors is the rate at which information can be fed into the machine and, even more so, the rate at which the result of the calculations can be read out. Input speeds of 300 to 1000 characters per second are usual compared with output rates of 100 to 600 characters per second. An operator punching tape or cards to feed into the input mechanism can achieve rates of the order of 6 characters per second. Other information may be obtained in the form of analogue signals and direct analogue/digital conversion may be used. Within the machine it must be possible to refer rapidly to relevant instructions and parts of the calculation. Using ferrite cores, access to a number can be made in a few microseconds but, since they are expensive, cheaper and slower magnetic bulk stores are used in conjunction with them. Maximum advantage is only achieved by combining the simple sequences of instructions with great ingenuity in the optimum programme for the machine. Autocodes have been developed to facilitate programming for basic operations on a given machine. MR. REDISH, in his presentation, stressed the difficulty to the outside user, taking time on several machines as available, of finding that the operators of each machine then develop their own particular routines for certain more complicated types of operations. The programme taking advantage of a routine on one machine may not then be run on another of the same make, for it, too, has its own special "dialect". He called for the need to standardize programmes. Others in discussion thought this was expecting a great deal of co-operation between different industrial users for relatively little gain to themselves. However, where one organization possesses more than one digital computer it may readily be found convenient to run a programme on different machines according to their commitments. To find then that each has its own dialect and that the programme must be consequently modified is a great nuisance.

In his paper MR. REDISH referred to the distinction between calculators and computers being mainly in the size of the store which, in the case of the calculator, contains very few numbers and no instructions; instead, the instructions are read in as required or are semi-permanently set up, for example, on a plug board. Analogue computers really belong more to the calculator class as yet. They are particularly valuable when undertaking dynamic studies on systems for which comparatively restricted precision only is available.

One contributor to the discussion expressed himself forcefully on the undesirability of talking simply of analogue and digital computers. He used the simile of the range of electric motors generally available to stress the range of potentialities in available computers.

Computers in Research

MR. RIJNSDORP'S paper illustrated the application of digital and analogue systems in the particular field of distillation dynamics research. He pointed out how the two systems are complementary. Digital computers are more suitable for making logical decisions and solving algebraic equations, whereas an electrical analogue is more suitable for the solution of differential equations.

Since multistage fractional distillation processes can only be described adequately by a complicated mathematical model, computers are necessary. Fortunately, much practical work has already been done in this field and the relevant parameters for the model are better known than, say, for chemical reactor design.

The calculations for the design of the column involve algebraic equations repeated for each tray which may be readily programmed for a digital computer. By carrying out a series of steady-state calculations, the response of a column to changes in different conditions may be estimated. MR. RIJNSDORP referred to the work of others on this. Such methods, however, take a long time on a digital machine and there are many complications which make it a laborious way of assessing alternative control systems, even though it is capable of giving good insight into column behaviour.

On the assumption that pressure is constant, that liquid and vapour flow variations travel through the column with negligible time delay and heat transfer changes in the reboiler and condenser are instantaneous, all differential equations, other than the partial mass balances, are simplified to algebraic equations. To tackle such a problem a large analogue machine is needed for all but binary systems in columns of very few stages. When ternary or above mixtures are encountered the method is less promising still. Alternatively, the binary case may be satisfactorily solved on digital computers by conversion of the differential equations into difference equations using a finite time increment.

For a realistic study of control system response it is important to consider fast dynamic effects so that the initial character of a deviation consequent upon a disturbance can be followed. Variations in pressure drop, liquid and vapour hold-up and so on must then be considered in column dynamics. Doing this without additional assumptions takes excessive time on a digital machine, and it is also necessary to introduce certain other assumptions if the analogue for its simulation is to be kept within reasonable size. The Shell Group had used the imaginary transformation, j, to transform the differential equation into algebraic equations which could be solved on a computer. However, a marked discrepancy was observed between the calculated and measured lowest tray composition response to sinusoidal variations in the reboiler steam supply. This, after subsequent experimental work on tray columns, was found to be due to an inadequate picture of what happened as a result of the disturbance. A sudden given increase in vapour flow causes an immediate and much greater liquid overflow from the trays than generally expected. The consequence of this is developed at some length in the paper and, as referred to above, much of the discussion on this paper was taken up with this aspect of the work. MR. RIJNSDORP then went on to describe in outline features of the analogue machine which they had built to simulate the dynamic behaviour of plate distillation columns. In this, allowance was made for the coupling between vapour and liquid overflow transients, though no allowance was made for entrainment. MR. RIJNSDORP stressed the advantage of being readily able to alter parameters in analogue systems so that the effect of these on response could the more readily be followed.

Computers in Management

MR. THOMPSON'S paper outlined how the Esso Petroleum Co. at Fawley had utilized a digital computer for operations planning, investment control and cost control.

One method of assisting operations planning is to simulate the overall refinery operations by writing into the programme of the planning operations equations all the known operating restrictions. This had been done on the Fawley IBM 650 for the Esso Refinery at Milford Haven. Two principal difficulties encountered were the lack of flexibility of the method and the difficulty of handling such a complex problem on the relatively small computer. A much more flexible alternative method assisting in operations planning is linear programming. By this method all operating restrictions are handled as a series of inequalities and the solution is derived which maximizes the criterion of merit. The

linear programming model of Fawley Refinery involves a matrix of over 300 unknowns and 300 equations. Using this, operating procedures have been discovered which, because of the complexity of operations, would not otherwise have been appreciated to be economically advantageous. This method can be utilized to particular advantage in the assessment of marginal production economics.

MR. THOMPSON mentioned that they have available at Fawley some 70 programmes for fundamental chemical engineering calculations. Many of these are available from the IBM library; others they developed themselves or received from associates in the U.S.A. Approximately one-third of the capital at Fawley is invested in non-processing equipment such as lines, tankage and jetties. So, besides the use of the computer in process equipment design and cost assessment, it has been used to optimize the investment in these other facilities too. Use of a stochastic model of oil movements developed from operational research studies has also greatly aided the utilization of available facilities at Fawley and Milford Haven and speeded the turn round of tankers.

Given efficient data reporting systems, a digital machine readily furnishes daily analyses of plant performance and, at small additional cost, can calculate, for example, the most economic date for recharging a reactor with catalyst. Stores holdings can be under constant review and information on both operating and constructional costs can be readily furnished. In all of this, management is able to assess the operating costs against the general long-term trend and any marked deviation is immediately apparent.

MR. THOMPSON was not able to tell the meeting the direct economic advantage of the digital computer to his company, but he did say how necessary a facility he considered it to be. In their initial survey justifying the acquisition of the computer many uses were considered. Though these showed advantage, subsequently they found its principal value lay in less obvious uses which without its availability they could not have discovered.

Computers in Control

MR. GALLON'S first paper of the afternoon session discussed the need for more computation in process control. He pointed out that, in general, the control systems at present installed on plants are adequate in attenuating the disturbances which occur. Settings, however, must be made from experience and the operations cannot be maintained at their optimum without further intervention, whilst, for example, catalysts deteriorate. It is possible to adopt the statistical techniques of evolutionary operation. Provided one can define an adequate performance index from process measurements, it is obviously possible to programme a computer to reset controllers by the evolutionary technique. If, however, adequate knowledge of the relationship between inputs and the performance index is known, there is the greater potentiality of using the computer to reset the relevant controllers as disturbances in input variables are detected—feed-forward control. The technique of evolutionary operation is slow, but any feed-back loop has the advantage that the result of adjustments is observed. There is the possibility of a combination of feed-forward and feed-back systems. General control to be achieved by a feed-forward system and the inadequacies due to defects in the mathematical model of the process response are refined by a feed-back optimizing system.

MR. GALLON looked forward to a hierarchy of computers whereby conventional controllers and/or smaller on-line controllers using both analogue and digital systems are reset by an overall "managerial" computer. Such a system should be programmed, for example, to make the relevant management assessments of refinery operations. Since large computers tend to be more economical thereafter than small ones, he saw the possibility of time-sharing systems being developed more and more for the very largest computers.

Subsequent discussion emphasized the point that the comprehensive study of process response necessary before embarking on a large computer installation should show remarkable results if it was also undertaken in the design of a conventional control system. In his paper MR. THOMPSON had quoted the suggestion of STIRLING and HO that any return greater than a 5 to 6 per cent per annum saving from a process computer controller probably indicated that the original system was radically at fault.

Again in this symposium, too, the need for better information about process response on which design may be based was stressed by different sides of the audience. There is the prospect that the computer will, at the same time, control the process and accumulate knowledge of response characteristics.

The paper by MESSRS. REDDING and BODLEY described the well-tried Evershed & Vignoles simple computing relay. This elegant but robust electromagnetic balance operated on current analogues of the relevant process variables. By suitable coil arrangements it can evaluate an equation of the form

$$(ax \pm by)\ cz \pm s + (pu \pm qv)rw = 0$$

where a, b, c, p, q, and r are fixed or adjustable coefficients, s is developed by an instrument spring and u, v, w, x, y and z are variables, any one of which may be the output variable. The device is intended to operate with such simple algebraic equations computing steady-state effects and is therefore complementary to the conventional controller which is designed to deal particularly with transitory effects. One computing device may readily feed several controllers.

Many of the difficulties encountered in the design of control systems stem from the need to infer some process criteria from the magnitudes of several interrelated variables; for example, the progress of reaction from temperature, pressure and reactant flow measurements. Such a computing relay allows the signals to be combined into one which is more directly related to the condition it is desired to control.

A particularly interesting process control problem solved using the relay was encountered in glass production. Usually glass furnaces have been gas fired and temperatures estimated using radiation pyrometers. Because of thermal capacity problems, control was usually erratic. However, molten glass is a good electrical conductor and its resistance is virtually linear over the temperature range of this application. Hence, if the resistance is maintained constant between two electrodes in the glass, this is a criterion of constant temperature. The computer was used to determine this by application of Ohms law to the heating current supplied between the two electrodes. Deviation of resistance and hence temperature from the set limits switched a motor driving a transformer tapping supplying power to the melt. By this means the lags largely causing control difficulties were eliminated. Their other example described a gas blender designed to blend refinery gas products with an inert to give a final blend of required density and calorific value.

The next paper, by MESSRS. JAMES and LEE, described the "Anatrol" on-line process control computer and its possible application. The machine employs a time-sharing principle to obtain the maximum calculating potential from the minimum of computing elements. Up to 25 steps are available through a switch system, so that, with three amplifiers and one multiplier, the machine approaches the capabilities of a 75-amplifier, 25-multiplier unit. Inter-step results are stored on condensers for use later in the calculation sequence and longer-term stores are also available. With an operating sequence speed of the order of seconds, it is readily capable of controlling processes with response

times of the order of minutes. Built on a module basis, computing elements may be incorporated as necessary. Good reliability is claimed for the conservatively rated components and the machine is arranged to check all its electronic units every 25 seconds or so. Input/output checks may be carried out less frequently and the freshly computed value is checked against previous values before being passed to a controller.

Such a computer installation (costing of the order of £4,000 to £12,000) may well operate directly or in a supervisory capacity, adjusting conventional controllers in a feed-forward control system. However, for this there is the limitation that an adequate process response model shall be available. There is the further possibility that the system will be operated in conjunction with an optimizer unit to achieve an adaptive control system. The Anatrol computer readily fits into a hierarchical control system and its manufacturers envisage this general development in which on-line Anatrol computers will be adjusted by a master computer for overall control.

The final paper, by MR. W. F. M. PAYNE, described the Argus digital computer. (The control system using this may cost of the order of £50,000 to £150,000.) Again module construction has been adopted. The various arithmetical and logical operations of the computer are carried out by printed circuit units which are plugged into the unit according to the scope demanded. Data is stored by ferrite cores, some of which are also used to store the programme which is set by pegging the core boards. Side routines as necessary are programmed to monitor the operation and deal with emergency situations. Also, since process information is usually available in an analogue form, an analogue digital conversion system is necessary. Because of expense, one only is generally used, switched in turn to each input as it is scanned. Even so, the machine is capable of checking several hundred inputs per second.

Basically, the machine readily operates as a logging/alarm monitoring installation. This may be extended to diagnose plant disturbances quickly, accurately and reliably. Digital signals lend themselves to sequential operations such as the safe start up of a critical unit. Again the digital computer can be programmed for feed-forward control if an adequate model of the process is available or, if not, it may be programmed to introduce small controlled disturbances and, from an analysis of their effects, to develop a model. The machine has a considerable capacity for accumulating information but, in general, it would only be programmed to print out as a routine feature that which is important for process records.

In discussion, some members present, with an interest in simple controllers having an optimizing strategy, pressed their economic merits relative to the much more complex feed-forward computer control systems. However, it is apparent that the simple optimizer working from a feed-back system cannot smooth out the effects of "supply fluctuations" in the way it may be done with a feed-forward system and so must operate at a higher product give away than is necessary with the combination of feed-forward control and an optimizing strategy.

Present Position

Many are becoming familiar with applications of computers in chemical engineering research. Methods are becoming more sophisticated and powerful with the increasing ingenuity of the programmer. In the field of management, too, computer applications are now increasingly well known. MR. THOMPSON'S point is very valid in all spheres—until you have a certain facility you cannot fully judge its potentialities. It is in the field of automatic control applications, however, that the chemical engineer and control engineer stand on the frontier. From the United States we read more of possibilities rather than current successes. Indeed, it is hard to assess how many on-line computer systems are in actual operation there, but it is heartening to know that I.C.I. in this country in one tried process are installing an Argus computer. They have sufficient confidence in its reliability to use it to replace rather than supervise the hundred or so conventional controllers otherwise needed. Also, it is believed that another organization is going to install an Anatrol computer control system. We hope that it will not be long before we hear a report of process experience with such advanced computer controllers from this country.

Research at the National Chemical Laboratory

ACCORDING to the annual report* just issued, a number of investigations have been carried out on the chemical extraction of beryllium from low-grade ores, using flotation concentrates arising from ore-dressing research at the Warren Spring Laboratory.

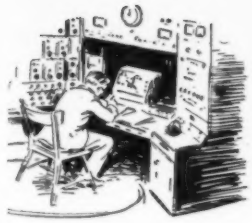
A modified rotary-film disc contactor with 16-in. discs has been developed for the solvent extraction of uranium from ore slurries. It can deal with 30 lb/hr or 720 lb/day of dry ore on a continuous run, and a similar contactor with 40-in. discs is under construction which may handle one ton of dry ore per day.

Also described is a process for the heap leaching of uranium ores, a development of natural leaching in which sulphuric acid is produced by the action of rain and of atmospheric oxygen on pyritic ores. In addition, two new series of experiments have been carried out on the separation of rare-earth elements, and a continuous sodium-amalgam process for removing samarium, europium and ytterbium from concentrates has been operated. A new and rapid solvent-extraction method is being studied in which aqueous solutions of lanthanons are extracted by tributylphosphate.

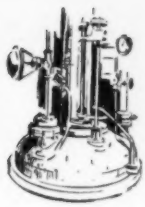
Some of the most important work of the National Chemical Laboratory is being under taken by its Chemical Thermodynamics Group, which is concerned with the precise determination of the energy changes accompanying chemical reactions over a wide range of temperatures. This work requires an enormous amount of effort, and because of the large number of readings required special equipment has been designed and built by the Laboratory. This equipment will provide a high degree of automation in measurement and recording as well as in control.

The Director, Dr. J. S. Anderson, is himself in charge of a research group concerned with uncontaminated metallic surfaces. This group is studying physical processes and chemical reactions on absolutely uncontaminated metallic surfaces, obtainable only at ultra-high vacua. The aim is to study the mechanism of chemical reactions which take place on solid surfaces. An absolutely uncontaminated surface is extraordinarily reactive, and practically every molecule colliding with it undergoes reaction.

* Report of the National Chemical Laboratory, 1960. Published for D.S.I.R. by H.M.S.O. Price 4s. 6d. net, 4s. 11d. by post (81 cents U.S.A.).



LETTERS TO THE EDITOR



Sieve Trays for Distillation Columns

Dear Sir,

In the February issue of your magazine was published a comment of MR. AUCHER* from the L'Air Liquide Company, concerning the "Sieve trays for distillation columns", patented by the above-mentioned company, that I described in my article, published in your magazine in November 1960.

I beg to inform you that the above-mentioned patent was known to me, and that in my original article, published in the Czech magazine, *Kvasny Prumysl*, No. 4, 1959, I specifically stated that the sieve trays were submitted to patent registration. It appears, through the fault of the translator, the reference to the French company's patent was omitted from the more abbreviated English version.

I remain, sincerely yours,

ING. B. MELICHAR

Hradec Králové,
Czechoslovakia.

Cyclonic Film Evaporator

Dear Sir,

In your November 1960 issue there is an article describing "A New Cyclonic Film Evaporator"* recently developed by the Russians. It is claimed that "a feature of the apparatus is the tangential input of the solution into the upper part of the tube and its high-speed filmwise downward flow along the inside of the tube".

According to the description, the investigations were carried out with a single tube 7 metres long and 57 mm in diameter.

There is really nothing new in this idea and we can well understand that excellent results were obtained with a tube of this configuration and with the arrangement of tangential inlet to the top of the tube, since we have built these evaporators for over 50 years.

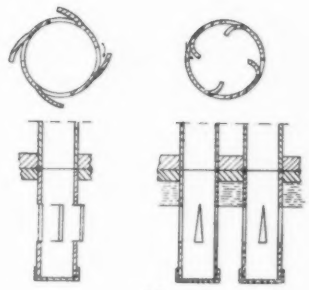
The basic design of the "Cyclonic Film Evaporator" is disclosed in PAUL KESTNER'S British Patent Specification No. 5020 dated February 28, 1910, and various methods of making the tangential entry at the top of the tubes are shown in the illustrations accompanying the patent.

We would mention that in certain designs of Kestner falling film evaporators which we make today the "Cyclonic Film Principle" is still used to great advantage, although the detailed method of manufacturing tangential inlets at the top of the tubes has been considerably improved.

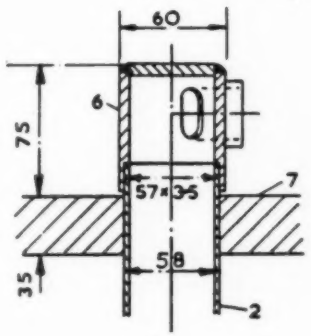
Yours faithfully,

BRIAN N. REAVELL,
Chairman.

Kestner Evaporator & Engineering Co. Ltd., London, S.W.6.



(*a*)



(*b*)

Editor's Comment:

We are naturally pleased to place the credit for the cyclonic evaporator idea where it rightfully belongs. However, the article in which we described the Russian evaporator did not claim originality for the idea, but for the design as a whole. The diagram (a) above, provided by Mr. Reavell, shows Kestner's patented device, while (b) shows the tube cap used in the Russian evaporator and gives dimensions. It would have been interesting to have seen the tube caps referred to by Mr. Reavell, especially as we were unable to find any reference to them in Kestner's current literature.

Dear Sir,

My attention has been drawn to the announcement in your issue of December 1960 headed "A cost engineering association for Britain", in which it is suggested that the new association is the first professional body in this country to be concerned solely with costing.

The Institute of Cost and Works Accountants, which was incorporated in 1919, is the professional and examining body specializing in the subjects of cost and management accountancy. One of the Institute's main objects is to promote the study and adoption of scientific methods in cost accountancy as a means of securing maximum efficiency in industry and commerce.

Admission to the Institute's two grades of membership—Fellow and Associate—is solely by way of stringent examination and extensive practical experience, and I think that our 7000 members and 17,000 registered students would be justified in taking some exception to the claim of the Association of Cost Engineers to be the first in this field in Britain.

Yours faithfully,

DEREK DU PRÉ,
Secretary.

The Institute of Cost and Works Accountants,
63 Portland Place,
London, W.1.

Association of Cost Engineers

Dear Sir,

The publicity which you have given to the British Group of the American Association of Cost Engineers in your journal appears to have given rise to some confusion as to its aims and objectives. Cost engineering concerns itself with the engineering for estimation, cost control and profitability studies, mainly of capital projects, and does not, generally, deal with the accounting for expenditures actually incurred, except in so far as records of past expenditure are required to control and assess anticipated future expenditure. There is undoubtedly an area of overlap in the sense that the units into which we break down the commodity which we are dealing with should ideally be the same for the cost accountant and the cost engineer. The stress is on the engineering function; i.e., the American Association of Cost Engineers caters for the *engineers* engaged in the planning and control of works from the cost aspect. It is in this sense that A.A.C.E. claims to be the only body at present.

It is the declared aim of this Group, which is at present a regional British section of the American organization, to transform itself, in due course, into a British body which will provide a professional status for its members by suitable tests of qualification, and to cater for the educational aspects of cost engineering.

There are many problems which are common to both the cost accountant and the cost engineer, and as Chairman of the British Group I sincerely hope that we shall find ways and means of actively working together in establishing our respective techniques. Terminology is one obvious area where co-ordination is imperative; data processing is another.

Yours faithfully,

J. H. HERBERT,
Chairman, British Group, A.A.C.E.

Kellogg International Corporation,
Kellogg House,
7-10 Chandos Street, London, W.1.

Abstracts

GROUP A — FLUID DYNAMICS

Mixing of Solid Particles in a Cylindrical Tank Equipped with Paddle-type Impellers

The authors studied the mixing mechanism of the powder mixtures sand/NaCl (32-42 mesh) and Na_2CO_3/PVC (100-200 mesh), and determined the relationships between the degree of mixing and the operating variables given by the equations:

$$\frac{\sigma}{\sigma_0} = 0.676\,(N\theta)^{-0.48}\left(\frac{D_I N^2}{g}\right)^{-0.16}\left(\frac{D_T}{D_I}\right)^{0.89}\left(\frac{R_I}{D_I}\right)^{0.57} \text{ and}$$

$$\frac{(\sigma/\sigma_0)_c}{(N\theta)_c} = 6.18 \times 10^{-6}\left(\frac{D_I N^2}{g}\right)^{-0.52}\left(\frac{D_T}{D_I}\right)^{0.80}$$

By analogy with diffusion, the apparent diffusivities were evaluated from the concentration distribution of the two kinds of particles. The relations between the apparent diffusivities and the operating variables were obtained from:

$$\frac{D_S}{N D_I^2} = 5.75 \times 10^{-3}\left(\frac{D_I N^2}{g}\right)^{0.18}\left(\frac{D_T}{D_I}\right)^{0.46}$$

The theoretical degree of mixing agreed closely with the observed one and the authors concluded that diffusion mixing occurs in mixing powders with paddle-type impellers. In these equations N is rpm, θ is mixing time, D_I and D_T are impeller and tank diameters, R_I is radius of marked solids, D_S is apparent diffusivity of marked solids in the tank, all in c.g.s. σ_0 is standard deviation of the total samples in the perfectly mixed state and σ is standard deviation of the concentration of marked solids in any sample, from the concentration of marked solids in the mixture, both in wt. per cent. 9 refs.

T. OTAKE *et al.*, *Chem. Eng., Japan*, 1961, **25** (3), 178-86.

Liquid-liquid Dispersion in Co-current Flow Through Orifice

Organic liquid droplets (benzene or ethyl acetate) were passed through orifices 1.34, 1.10 and 0.85 cm dia. co-currently with water, and their dispersion due to local turbulence induced by the orifice was observed. The experimental pressure drop through the orifice agreed closely with the calculated value, and the dissipation energies were expressed by:

$$\epsilon = \Delta p'\, g_c G/\rho_c w$$

Finally, HINZE's equation:

$$\rho_c \sigma D_{95}/\mu_c^2 = 0.725(\mu_c^5 \epsilon/\rho_c \sigma^4)^{-2/5}$$

correlated the experimental data successfully. $\Delta p'$ is overall pressure loss across orifice, ρ_c refers to the continuous phase, G is mass flow rate, w is mass, σ is interfacial tension, g_c is a conversion factor and D_{95} is the value of drop diameter in which 95 per cent by volume is contained, all in c.g.s. units. 5 refs.

T. SHIROTSUKA *et al.*, *Chem. Eng., Japan*, 1961, **25** (2), 109-13.

Data on the Vertical Flow of Air-water Mixtures in the Annular and Dispersed Flow Regions. Part II: Film Thickness and Entrainment Data and Analysis of Pressure Drop Measurements

Further data obtained by BENNETT are presented, including measurements of film thickness and entrainment. Analyses carried out by the authors on these measurements, on the pressure drop data presented by BENNETT and THORNTON and on the interrelation between the two sets of measurements are also presented.

The knowledge of film thickness and film flow rate allows much more comprehensive analysis, and treatments based on the theories of ANDERSON and MANTZOURANIS and CALVERT and WILLIAMS have been carried out. Complete data were obtained by BENNETT for low liquid flow rates only and in this region large deviations from the theories occur. Some of these discrepancies are explained and the theories corrected, but large deviations still exist at low film thicknesses and can only be qualitatively accounted for.

The entrainment data have been presented in terms of the empirical correlation of DUKLER and WICKS. Although good agreement with this correlation is observed for high entrainment, systematic deviations occur at values of low entrainment.

J. G. COLLIER and G. F. HEWITT, *Trans. Inst. Ch. E.*, 1961, **39**, 2, 127-36.

GROUP B — HEAT TRANSFER

Heat Transfer to Staggered Banks of Tubes from a Fluid in Cross Flow

From experiments upon staggered banks of closely packed tubes up to 20 rows deep, a formula is proposed for calculating the film heat transfer coefficient at the outer tube walls. The author uses the geometrical factor $A = (s_1/d - 1)\,(s_2/d - 1)$

where d = tube o.d.;
s_1 = pitch of tubes transverse to flow;
s_2 = diagonal pitch of tubes.

In the following two equations

$$\text{Nu} = [0.296 + 0.065(A - 1)]\ \text{Re}^{0.6}$$

which applies when $A > 1$ and

$$\text{Nu} = [0.296 + 0.032(A - 1)]\ \text{Re}^{0.6}$$

which applies when $A < 1$: a nomogram is presented for the solution of these equations.

V. L. TOLUBINSKY and V. M. LEGKY, *Teploenergetika*, 1961, **3**, 53.

Film Coefficients for Glass-lined Reactors

A nomograph is presented to speed calculations for the overall heat-transfer coefficients for glass-lined steel reactors given by the formula:

$$h = \frac{0.33k}{D}\left(\frac{L^2 N\rho}{\mu}\right)^{\frac{2}{3}}\left(\frac{C\mu}{k}\right)^{\frac{1}{3}}\left(\frac{\mu}{\mu_w}\right)^{0.14}$$

where L = paddle diameter, N = agitator speed rph, and other symbols have customary significance.

G. M. MACHWART, *Chem. Eng.*, 1961, **68** (8), 204.

A New-type Forced-flow Evaporator

A description of a new design of Hungarian evaporator, which may be considered as basically a Kestner apparatus in which the surface is arranged as two concentric bundles connected in series. The application of forced flow prevents the decomposition of sugar and increase in depth of juice colour, because of the rapid passage of the juice at a high specific evaporation rate and high heat transfer.

T. NYARY, *Cukoripar*, 1960, **5**, 141-2.

Determination of Heat Losses in Industrial Furnaces

This paper offers simple equations involving only addition and multiplication for calculating. Equations are given for losses by convection and radiation and for the summation of the two. Simplified functions are presented for calculation of coefficient for surfaces at various angles, with varying values of radiation. A further simplification allows to be calculated for geometrical solids of any form. It is shown that the degree of error introduced by this simplified method is not excessive. Examples of application are given.

K. LUDERT, *Energetyka Przemysowa*, 1961, **IX**, 85.

Burn-out in Liquid-cooled Reactors

This paper outlines the problem of burn-out for liquid-cooled systems—the point where a self-heated element will burn out because of the heat flux—and discusses the hydrodynamic and heat-transfer characteristics of a tube in which liquid is being totally evaporated.

J. G. COLLIER, *Nuc. Power*, 1961, **6** (62), 61-6.

Vibration and Pulsation Boost Heat Transfer

A report on recent developments in heat transfer in conditions of vibration and pulsation. 67 refs.

R. LEMLICH, *Chem. Eng.*, 1961, **68** (10), 171-4.

Thermal Conductivity of Two-phase Materials

A two-parameter equation is derived to express the effective thermal conductivity of two-phase heterogeneous materials. In addition to bulk porosity, a second parameter related to the spatial distribution of the two phases is also included in the equation. Both parameters can be experimentally measured. 6 refs.

G. T. N. TSAO, *Ind. Eng. Chem.*, 1961, **53** (5), 395-7.

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GROUP C — MASS TRANSFER

Mass Transfer and Chemical Reaction in Liquid-liquid Agitation Systems

The authors measured the interfacial area and the overall reaction rate for various liquid-liquid agitated systems. They found that for systems where density difference is zero the overall rate of reaction, at low agitation levels, is proportional to the agitation intensity. However, at higher agitation speeds the increase in the interfacial area is not accompanied by an increase in overall reaction rate. Thus in liquid-liquid reaction systems there is sometimes an upper limit to the effective agitator speed.

S. NAGATA and I. YAMAGUCHI, *Chem. Eng. Japan*, 1960, **24** (10), 736-40.

Rate of a Transfer Unit—A New Correlating Factor for Heat and Mass Transfer

The author proposes a new rate factor, the Rate of a Transfer Unit, for the transfer of heat and mass between two phases in intimate contact, especially where transfer is through a geometric shape surrounded by a film. Equations and graphs are presented and an example of use of the new factor is given. 8 refs.

E. H. LEBEIS, JR., *Ind. Eng. Chem.*, 1961, **53** (5), 349-56.

Prediction of Binary Vapour-liquid Equilibrium Data

The authors propose an empirical method for predicting binary vapour/liquid equilibria at various isothermal and isobaric conditions, from equilibrium data for the system at one condition, isothermal or isobaric. The method does not involve a trial-and-error procedure, it is simple to use, and has given good results with eight non-azeotropic systems. 11 refs.

J. C. K. HO and B. C. Y. LU, *Ind. Eng. Chem.*, 1961, **53** (5), 384-6.

Gas Absorption Review

A review of recent advances in gas-liquid correlations as they can be used in gas absorption processes. 46 refs.

M. LEVA and C. Y. WEN, *Ind. Eng. Chem.*, 1961, **53** (5), 417-18.

Mass Transfer from a Wetted Porous Surface to a Current of Air

For evaporation from a porous surface across which air is flowing, the authors derive equations which refer to air in turbulent flow. The conclusions arrived at are that mass transfer in the direction of air flow is analogous to heat transmission under the same conditions of turbulence and the average mass transfer rate for all the porous walls tested is proportional to $Re^{0.8}$ and may be represented with fair accuracy by the equations presented. However, near the entrance section at low flow rates the mass transfer is complex and cannot be described by a single equation.

V. P. ISKACKENKO and V. V. VZOROV, *Teploenergetika*, 1961, **3**, 57.

GROUP E — PROCESSING

Fischer-Tropsch Synthesis with a Fluidized Iron Catalyst

Hydrocarbon synthesis was studied in a 2-in.-dia. fluidized column, using a CO-rich synthesis gas with Fe-Cu-MgO-K_2O catalyst. The results were compared with those available in the literature.

CO conversion was high (95 per cent), but much of the CO was converted to CO_2. CH_4 formation varied with space velocity. The usage ratio (U H_2:CO) was lower than the H_2:CO ratio of the inlet gas. It was a function of H_2 content of the synthesis gas and the time of contact in the range 40-60 per cent H_2.

Activation energy was 19.6 K cal/mol. Liquid hydrocarbons contained about 35 per cent unsaturate. Catalyst activity was high, 450 ml gas/ml cat/hr at 300°C, and proportional to pressure. Activity was maintained for about 130 hr. Carbon deposit was then 20 per cent of catalyst mass.

N. G. BASAK *et al.*, *Chem. Age, India*, 1961, **12** (1), 14-22.

Investigation on the Elimination of Aniline and Nitrobenzene from Production Wastes

A method for the purifying of wastes from aniline production by sorption on activated carbon was examined in both static and dynamic systems. The static sorptive power was about 0.20 g/h and the dynamic about 0.10 g/h. The lower sorptive power of carbon in the dynamic process can be ascribed to the use of filters with a relatively low filling layer. The use of columns with a higher filling layer would raise the sorptive capacity of the adsorbent accordingly. The optimal rate of the waste flow through the column was found to be about 1.5 m/h. The sorbent was regenerated and the aniline and nitrobenzene recovered by means of superheated steam at 160°C. Activated carbon adsorption is suitable for the recovery of aniline and nitrobenzene from waste waters arising from aniline manufacture, for the recovery of aniline directly from water used in aniline production, and for the recovery of aniline from other products. 6 figs. 6 tabs.

K. BURDECKI, J. KUCHARSKI and A. STERNINSKI, *Przemysl Chemiczny*, 1959, **12**, 753-6.

* Author's abstract.

The Use of Aluminium and Iron Salts Waste for Purifying Waters and Factory Wastes

An acid solution containing salts of Al and Fe was used as coagulant in the experiments, since its composition closely resembled the waste from the production of aluminium oxide and the composition of slime in slime heaps of a superphosphate factor. The optimum dosage for artificially adulterated waters was found to be 100-200 mg/l. The waste slimes were good coagulants, provided the upper layers washed out of heaps by rain were not used. The optimum dosage of slime is 0.3-0.7 g/l, and changes in pH occurring during the purifying process are insignificant. The method is of value, since it eliminates the use of costly aluminium sulphate and provides an outlet for wastes which hitherto have had either to be discharged to sewers or stacked in heaps. 3 figs, 8 tabs.

A. MAZARSKI and J. KUCHARSKI, *Przemysl Chemiczny*, 1959, **12**, 756-60.

Hydrothermal Treatment of Natural Phosphates in a Cyclone Furnace

A process has been developed for subjecting natural phosphates to a severe steam treatment in a cyclone furnace heated by oil or natural gas. At 1450-1600°C (2650-2900°F) 95-99 per cent of phosphates were converted to the form soluble in citric acid, and the fluorine content of this product was less than 0.2 per cent. The fluidized bed furnace produced 1-2 tons/m^3/hr, and agricultural trials with the product were satisfactory. 8 refs.

S. J. VOLFKOVICH, *Chimie et Ind.*, 1961, **84** (4), 588-93.

Safe Handling of Chlorine Trifluoride

This report discusses the potential hazards of chlorine trifluoride and recommends a series of safe handling procedures. Particular emphasis is placed on the hazardous chlorine oxides and oxyfluorides, and a comprehensive literature survey on the preparation, chemical and physical properties, and stability of the individual chlorine oxides and oxyfluorides is included. These handling procedures are modified for bromine trifluoride.

R. L. FARRAR, JR., U.S.A.E.C. Research Development Report K-1416, 28 pp.

Oxidation Solves Waste HCl Problem

A new French process is reported which oxidizes by-product HCl to high-purity chlorine with 100 per cent conversion to oxygen-free chlorine. Operating costs are considerably lower than an electrolytic plant. The process operates in liquid phase at low temperature and atmospheric pressure, and employs an oxidizing mixture of nitric and sulphuric acids.

$2HCl + 2HNO_3$ (below 175°F) $\rightarrow$ $Cl_2 + 2NO_2 + 2H_2O$. Cl_2 and NO_2 are fractionated at 80 psi to 99.9 mole per cent Cl, and NO_2 is re-used.

Chem. Eng., 1961, **68** (9), 42-4.

Safe Handling of Plutonium in Laboratories and Plants

Plutonium is a fissile material and a very toxic radioactive substance. This report outlines the physical, chemical and toxic properties of plutonium, reviews the precautions to be taken in the design and operation of laboratories, plants and stores, and makes recommendations for safe practice. Criticality problems are briefly discussed.

G. J. APPLETON and H. J. DUNSTER, U.K.A.E.A. Report AHSB(RP)R6. Available from H.M. Stationery Office, 7s.

The Production of Pure Stabilized Uranium 233 Dioxide*

The first part of this report describes the purification, by butex extraction, of 30 g of U233 as nitrate, an account of experiments made to ascertain the optimum condition for precipitation of ammonium diuranate, and its ignition and reduction by H_2 to give an oxide which does not re-oxidize on exposure to air. The purified uranium has been processed to give an oxide of composition $UO_{2.03}$ suitable for reduction to metal with calcium.

The second part deals with two similar operations on 400 g and 700 g of U233 as nitrate (separated by solvent extraction from irradiated thorium) and discusses the purification by precipitation and conversion on a 100-g batch scale to a stable uranium dioxide suitable for reduction to metal powder.

L. AMEY *et al.*, U.K.A.E.A. Report AERE-R. 3550. Available from H.M. Stationery Office, 3s.

The Removal of Hydrogen Sulphide from Industrial Gases

The authors review the main processes which are used at present, and describe a new method which has not yet been applied industrially.

This method is based on the use of aqueous ferric propionate solutions, and offers the possibility of indefinite regeneration resulting in an expected low cost for the process. A feature of the process is that CO_2 is not removed with the H_2S. 34 refs.

H. GUINOT *et al.*, *Chimie et Ind.*, 1961, **85** (4), 561-75.

Brit. Chem. Eng. Abstracts: **FOLIO No. 18**

Book Reviews

Process Characterization
by H. J. Waterman, C. Boelhouwer and D. Th. A. Huibers
Elsevier Publishing Co., 1960, 140 pp.

THE authors have found that in many of the chemical processes they have examined in the fields of petroleum chemicals, fatty oils and sugars, the relationships between the relative amount of intermediate products (y) and final products (x) is of the type

$$Y = \frac{x(1-x)}{a+bx}$$

The process characterization seems to be the evaluation of "a" and "b" from empirical observations so that the hyperbola or a modification of it ($y = x + \frac{x(1-x)}{a+bx}$ fits the observed results. There is due warning against adopting this approach as a panacea, but some theoretical justification is put forward for cases which involve consecutive first-order reactions.

Having found hyperbolic formulæ useful in this form of correlation, the authors turn to physical chemical equilibrium data such as binary vapour-liquid equilibria and discuss in a convincing way the problems of data correlation and testing, in that field.

The section covering the fields of chemical reaction is as interesting for the experimental data incorporated in the many triangular diagrams as for the strict applicability of the basis of correlation suggested. One naturally thinks of the potentialities of other conic sections in this connection and is stimulated to reconsider the problem of "The Design and Analysis of Industrial experiments", of which the present work is a rather special facet. The work will be read with enjoyment and profit by those concerned with the development of chemical processes or with design problems involving phase equilibria. It provides, in passing, a good survey of these fields and a useful list of 149 references is provided.

The book is very well produced; there were, however, a few omissions of identifying letters for composition triangles.

K.L.B.

Coal Tar Fuels
The Association of Tar Distillers, 1960, London, 21s.

COAL tar fuels make an important contribution to the fuel resources of the country in these days of increased usage of liquid fuels. They are derived from British coals and have the advantage of a low sulphur content and high flame emissivity.

The authors of this new and wholly rewritten edition of the book *Coal Tar Fuels* are experts in the field of liquid fuels, especially of coal tar fuels, and they have been closely associated with the development of the fuels in recent years. The first chapter describes briefly the production of coal tar in the coal carbonisation process, then surveys generally the technique of coal tar distillation to give the valuable products, and finally shows how the different coal tar fuels are prepared. Chapter 2 concerns the composition and properties of the fuels, and emphasises particularly the importance of the carbon/hydrogen ratio and low sulphur content. In discussing the viscosity, it is pointed out that the fuels are in fact designated according to the temperature (°F) at which the fuels reach viscosities suitable for atomisation.

The combustion process is considered in Chapter 3, showing the theoretical amounts of air required for combustion of coal tar fuels, and the products resulting. Some interesting information follows on how a study of flame shape and flow patterns can be of practical use in improving furnace processes. Chapter 4 is valuable to chemical engineers concerned with designing the equipment for storing and handling the fuels. Several new nomograms have been worked out based on practical data.

The many types of burners, pumps, valves, heaters and other auxiliary plant equipment recommended are described in Chapter 5. Many illustrations and drawings are provided by the courtesy of manufacturers. In the final chapter on "Applications", the suitability of coal tar fuels for open-hearth furnaces and other types of metallurgical plant and for boiler plant and other purposes is demonstrated. The advantages originating from the low sulphur content and high flame emissivity in the particular use and the influence on fuel efficiency are stressed.

Advances in Cryogenic Engineering, Vol. 5
Edited by K. D. Timmerhaus
Plenum Press, $13.50

THE proceedings of the Cryogenic Engineering Conferences, now held annually in the U.S.A., have become part of the staple diet of the low-temperature physicist and engineer. Since the conferences were first instituted, there has been a gradual increase in both the quantity and quality of the material presented. The fifth conference, held in the University of California in September, 1959, bears out this trend.

Almost all the papers in these proceedings are related to the subject of rocketry. Some are concerned with the production and storage of liquefied gases, others with the properties of materials and methods of construction used in low-temperature equipment (including parts of rockets), whilst others discuss various phenomena occurring in cryogenic fluids. Amongst the exceptions is a paper describing the 72 in liquid hydrogen bubble chamber at Berkley; a paper describing recent developments of reversing exchangers by authors associated with Hydrocarbon Research Inc.; and a paper describing large-scale equipment for low-temperature distillation tray studies, by authors from British Oxygen Research & Development Ltd.

The construction of pipelines and storage tanks for liquefied gases is reported in much detail, together with reports of trials under steadier state and transient conditions. The phenomena occurring in liquefied gas containers when subject to sudden pressurisation are described. The latest developments in vacuum power insulation, including the new "Superinsulants", are presented. In the latter, alternate layers of reflecting metallic foil separated by thin layers of fibrous or cellular insulating material are used to provide a composite insulating structure of exceptionally low thermal conductivity.

Amongst the new gadgets and measuring devices presented are some new flow meters for cryogenic fluids, with accounts of their characteristics and accuracy. The papers describing the mechanical properties of materials at low temperatures include a number dealing with recent measurements on magnesium and aluminium alloys and on the new austenitic manganese steels.

Electronic Computers
by E. H. W. Hearsee
Blackie & Son, London and Glasgow, 1959, 110 pp., 27 figures, 12s. 6d.

THE author has tried, and succeeded, to present a difficult subject with simplicity, and has conveyed an understanding of the fundamental ideas which govern both digital and analogue computers. The book is also an introduction, a well-conceived introduction, into computer language and into the terms used by computer engineers.

A book like this was long overdue, because the greatest handicap in applying a new or novel technique for practical purposes is the difficulty of understanding the language in which computers are described. Once that barrier of understanding is removed and the basic principles understood (which is not so very difficult), we no longer stand in awe in front of the unknown but have the confidence of making use of the faculties built into complex calculating machines.

In chemical engineering use is already made of computers in trying to fathom out the uncertainties attached to every departure from an established process, and the more we wish to advance the greater steps are we compelled to take. Computers are an excellent means of speeding up development by their ability to solve elaborate problems rapidly.

As time goes by an increasing number of research chemists and chemical engineers will have to use computers, and the sooner they get an insight of the working of digital and analogue computers the better.

The author's style is very clear, interspersed with delightful aphorisms, of which one shall be quoted using the original italics: "Digital machines are capable of performing *any* mathematical calculation, provided its performance is *humanly* possible."

The book is recommended to students and engineers alike, and to those whose main concern is getting a job done.

L. A. STEINER

Abstracts

GROUP E — PROCESSING (contd.)

Nitration Review

This nitration review covers aromatics, aliphatics, nitrate esters, N-nitro compounds, heterocyclics and nitrants. 170 refs.
W. R. TOMLINSON, JR., *Ind. Eng. Chem.*, 1961, **53** (5), 401-3.

The Rectisol Process of Gas Ultra-purification at High Pressure

The Rectisol process was developed in connection with the Lurgi pressure gasification of low-rank coal. Low gas is purified continuously at high pressures by counter-current scrubbing with anhydrous methanol at −25 to −70°C. CO_2, H_2S, COS, CS_2 and gums are removed.

This paper describes the impurities in raw Lurgi gas and their removal by the Rectisol process.
E. R. SAUTER, *Chem. Age, India*, 1961, **12** (1), 34-9.

Ethylene Oxidation to Acetaldehyde

The article describes a German process of direct oxidation of ethylene to acetaldehyde. Features: cheaper raw material, high yields (95 per cent), low temperature and pressure operation, negligible by-products, minimum capital investment and utilities.

Catalyst is an aqueous solution of $CuCl_2$ with small quantities of PdCl. Reaction: $C_2H_4 + 2CuCl_2 + H_2O \rightarrow CH_3CHO + 2HCl + 2CuCl$. Regeneration: $2CuCl + 2HCl + \frac{1}{2}O_2 \rightarrow 2CuCl_2 + H_2O$.
Chem. Eng., 1961, **68** (10), 66-8.

Producing Acetylene in a Plasma Jet

Acetylene was produced by feeding methane into the "flame" of an argon-plasma jet. The argon-plasma jet was at 1200°K and acetylene yield 80 per cent. C_2H_2 is easily separated from the argon carrier and the H_2 produced as by-product. 6 refs.
H. W. LEUTNER and C. S. STOKES, *Ind Eng. Chem.*, 1961, **53** (5), 341-2.

Increasing the Capacity of Nitric Acid Plants by the Use of Commercial Oxygen

A mathematical investigation of the possibility of increasing the capacity of plants producing dilute nitric acid by the use of commercial oxygen revealed the following. (1) Partial or total substitution of the air by oxygen added into the denitrating tower will increase the amount of ammonia which can be processed with retention of the initial overall efficiency. (2) When the transfer capacity of the turbo-compressor is exploited to the full, the amount of ammonia which can be processed with the addition of oxygen will be determined by the sum of infiltrated air and the denitration air. (3) When less than the maximum amount of ammonia is processed, partial or complete substitution of the necessary denitrating air by oxygen will result in the increase of efficiency because of a decreased loss of nitrogen oxides. (4) The increase of the output of the plant by the use of oxygen will be economical only if the available oxygen is cheaper than that manufactured for this single purpose alone. (5) The capacity may be increased more economically by permitting some increase in the loss of nitrogen oxides than by manufacturing oxygen especially for this purpose. 1 fig. 4 tabs.
B. ENYEDI, *Magyar Kemikusok Lapja*, 1960, **15**, 5-6, 244-51.

Manufacture of Nitric Acid by the Oxidation of Ammonia—The Du Pont Pressure Process

The author discusses the historical development of the manufacture of HNO_3 by the oxidation of NH_3, and the development of the Du Pont pressure process.
T. H. CHILTON, *Chem. Eng. Prog. Monograph Series*, 1960, **56**, No. 3. Published by A.I.Ch.E.

Oxidation of SO_2 in a Reactor with Fluidized Catalyst

The application of fluidized V_2O_5 catalyst has vastly improved and simplified the production technology and reduced the initial capital costs. Among the numerous advantages are: practically total utilization of the active surface of the catalyst; intensive and efficient heat transfer, with 20-40 times increased heat-transfer coefficient (200 kcal/m² hr °C); good heat economy; the possibility of using concentrated inlet gas (up to 30 per cent SO_2); and easy automation and control. It was found experimentally that for optimum operating conditions the catalyst should be mechanically firm, spheroidal with 1-1.5 mm diameter, and the gas velocity 2-2.2 times the minimum fluidizing velocity (about 1.9 m/sec). Under these conditions the catalyst loss was only 4-7 per cent per month. Excessive velocity causes not only carry-over of catalyst, but backmixing as well, which slows down the reaction. The disadvantages of the fixed-bed reactor are put forward for comparison. 18 refs.
I. P. MUKHLENOV *et al.*, *Khim. Prom.*, 1961, **1**, 42-6.

* Author's abstract.

GROUP F — PROCESS CONTROL

Control Solids—Drying Equipment

The basic control problem in drying operations is essentially the same for rotary, travelling screws, moving sheet, tray and screw conveyor driers. The paper outlines a generalized drying system with reference to the many variables that influence the operation. A control system for spray driers is also shown.
A. H. MCKINNEY, *Chem. Eng.*, 1961, **68** (9), 79-82.

Electrochemical Gas Analyser (EKhG-5) for the Determination of Small Concentrations of SO_2

The automatic continuous electrochemical gas analyser was designed to measure the sulphur dioxide content of gases when the SO_2 concentration is between 0 and 0.5 per cent. The working principle of the apparatus is the continuous coulometric titration of SO_2 by iodine. The titration is carried out in glass container filled with 1.5 per cent solution of KI which is slightly acidified with sulphuric acid. There are two pairs of electrodes: viz., the "generator of the electrolysis" and the "indicator of the change in the iodine concentration". The gas entering the apparatus must be between 10 and 40°C, the sensitivity of measurement being highest at the maximum allowed temperature. The acid concentration continuously increases during the measurement and, depending on the SO_2 content of the gas being measured, the electrolyte has to be changed at 3-14-day intervals. If the gas contains any droplets or physical contamination, it has to be scrubbed before entry into the apparatus. The gas analyser can be used for the indirect determination of any such sulphur-containing compound which may be oxidized into SO_2 (e.g. H_2S, CS_2, COS, etc.). The first apparatus has been in use since 1959, serving a contact chamber, and it has ±5 per cent accuracy at the top reading.
N. K. FILATOVA, *Khim. Prom.*, 1961, **1**, 62-6.

Controlling Distillation Columns

The authors consider the dynamics of distillation and the instrumentation of the plant to show how proper control will help to produce pure products.
C. BERTRAND and J. B. JONES, *Chem. Eng.*, 1961, **68** (4), 139-44.

GROUP H — DESIGN

An Advance in Electrolysis of Alkali Chloride Solutions

A review of two years' experience of development of mercury cells. As a result of investigations, the author has designed a new type of electrolytic cell with mercury cathode for a 40,000 A load. The prototype was tested in the development section of the Chemical and Metallurgical Works, Usti-on-Elbe (Czechoslovakia).

The cell operates with a current density of the anode of up to 5000 A/m². The average energy consumption, inclusive of losses in the copper busbar powder supply, amounts to 3160 kWh/t of 100 per cent Naoh.
J. SUCHARDA, *Chem. Prum.*, 1961, **11** (5), 225-9.

How to Analyse the Calculations for Batch Rectification in Tray Columns*

To separate binary mixtures by batch rectification, determine optimum conditions by examining operation at constant reflux ratio or at constant composition of the overhead product.
J. COATES and B. S. PRESSBURG, *Chem. Eng.*, 1961, **68** (2), 131-6.

Flow of Oil/Gas Mixtures in Wells and Pipelines: Some Useful Correlations

General correlations have been obtained from 22 M.E. crudes, which enable the integrals ($vd\rho$) and $\rho d\rho$) to be evaluated for any pressure changes occurring in a well or pipeline. The correlations are 5-10 per cent accurate for oils of sp. gr. 0.80 to 0.90 (45° to 22° API) and they simplify the design of oil well flow-strings and flowlines so that it becomes similar to designing for single-phase flow. It is only necessary to know the saturation pressure and gravity of the oil to carry out flow calculations with reasonable accuracy. 8 refs.
W. J. BAKER and K. R. KEEP, *J. Inst. Pet.*, 1961, **47** (449), 162-9.

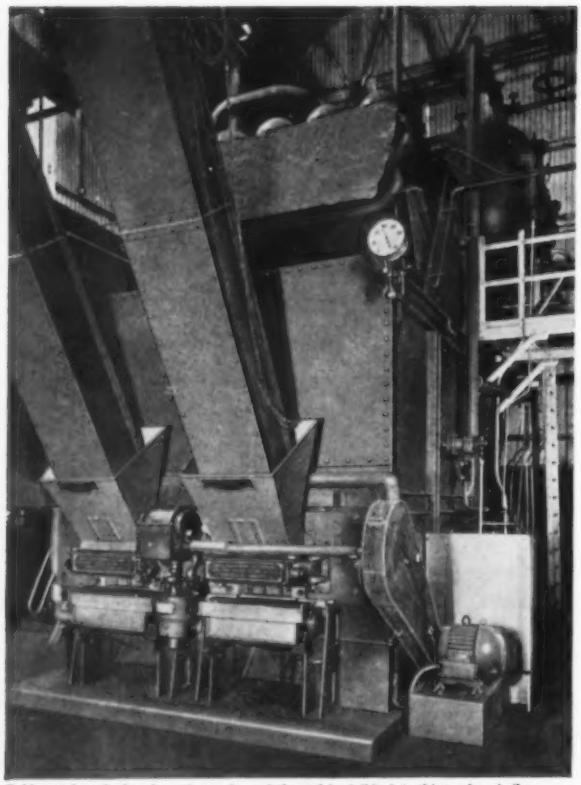
Design of Fluid-flow Distributors

This article presents a design approach to the type of fluid flow distribution that operates by parallel flow through a number of orifices. The design is based on orifice theory and two reasonable assumptions. Charts and nomographs are included.
D. R. RICHARDSON, *Chem. Eng.*, 1961, **68** (9), 83-6.

Brit. Chem. Eng. Abstracts: **FOLIO No. 19**

BCE 9960 for further information

COAL—properly used—is the cheapest fuel for the Chemical Industry



Coking stokers feed coal continuously, quietly and invisibly into this modern boiler.

Search the industrial scene—and it is difficult to find any major industry that does not use chemicals. But even in the prospering chemical and chemical processing world, sound economics are of primary importance and wise managements will always make every possible saving and every possible improvement that will help keep prices stable while satisfying—and expanding—their home and overseas markets.

BEGIN AT THE BEGINNING—THE BOILERHOUSE

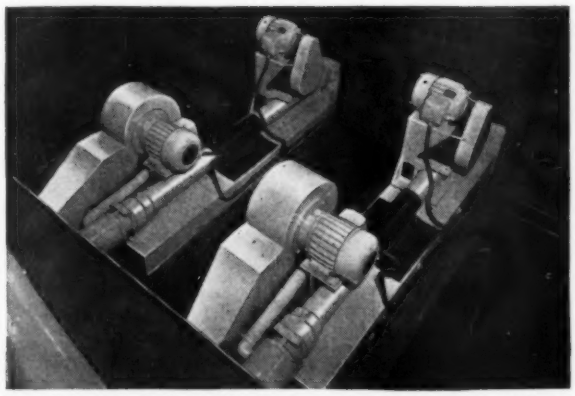
There are still some chemical plants that handicap their finances with outdated boilerhouses. To modernise other machinery while 'making-do' with inefficient boilers is to throw good money down the drain. Modern coal-burning installations can be so efficient that they will more than pay for themselves in a remarkably short time. They are, without question, the *first* essential in a chemical plant that is going to make rising profits for its management.

COAL IS THE RELIABLE FUEL

One question for any long-term planning is obvious: can supplies of coal be guaranteed? The answer is yes—without qualification. The mining industry—Britain's *largest single industry* is becoming increasingly efficient; its equipment is the best of its kind. And British coalfields contain enough coal to supply every industrial demand for centuries to come.

COAL IS CLEANER, HOTTER

Modern grading and washing methods ensure that coal is the most efficient and consistent fuel for every type of boiler—the ideal fuel for every section of the chemical and chemical processing industry. But to obtain the maximum heat at the lowest cost, coal should be mechanically stoked. A mechanical stoker automatically feeds the right amount of coal for the boiler load even when the load is varying; it burns coal at optimum efficiency all the time without the emission of smoke; and it virtually replaces the human element in boiler operation. There are many types of mechanical stokers, of which the most commonly used are the Chain Grate stoker, the Coking stoker, the Underfeed stoker and the Sprinkler stoker. Standard models are available for all sizes of boiler.



Two underfeed stokers feeding coal direct from a storage hopper into a modern vertical boiler.

OVER 80% OF BRITISH INDUSTRY USES COAL

The National Coal Board is determined that COAL shall continue to be plentiful, shall continue to keep our industrial power both dominant and progressive. You can depend upon COAL; its sources and supply are in our *own* hands, free from the fluctuations of foreign policies. Endless research by scientists and chemists working in the laboratories of the N.C.B. will ensure that coal will be increasingly profitable for its users.

DELIVERY—ON THE DOT —ON THE SPOT

The delivery of coal is today highly organised and completely reliable. Leading coal merchants have completely overhauled delivery and storage systems and are fully equipped to make sure that you get the right grade of coal when you want it and where you want it. And handling can be fully automatic. Furthermore, completely mechanised handling systems will transport coal from storage to furnace without any manual labour at all.

AND—WHEN YOU NEED IT— A NATION-WIDE FREE SERVICE

The vast resources of the National Coal Board are no further away than your telephone. At a flick of your finger, you can call upon one of the most comprehensive and efficient technical services in the world. No problem is too small or too big. You may want advice on coal quality, coal storage or coal-burning appliances or even on the siting of a new boilerhouse—whatever it is, a 'phone call or letter either to your coal supplier or to the Regional office of the National Coal Board will bring an authoritative answer to your problem.

FINANCE PLAN FOR INDUSTRY

No deposit, repayments spread over five years, low interest charges that can be set against Tax, full investment and other capital allowances, that can be claimed at once, these are the terms available to the manufacturer or businessman who wants to install modern coal-burning equipment without touching his capital resources.

Make use of the National Coal Board Industrial Finance Plan. The loans are made by Forward Trust Limited, who are members of the Midland Bank Group. A 'phone call or a letter to the Regional office of the National Coal Board will bring you full details.

SOLID FUEL—more heat at less cost—and it's British

PROGRESSIVE INDUSTRY IS GOING FORWARD ON COAL

ISSUED BY THE NATIONAL COAL BOARD

Abstracts

GROUP H — DESIGN (contd.)

Design of Apparatus for the Thermo-oxidative Pyrolysis of Hydrocarbon Gases

A completely new approach was put forward. While older designs were based on the laminar flow of the reactants and used several small, short, jet burners, the Soviet semi-industrial plant, installed in 1958, works at high gas velocities in the turbulent region and has only one special spiral jet burner head. (Experiments were carried out also with a three-jet burner head.) The aim was to produce acetylene from coke gas rich in methane (45 per cent) and with a high conversion. Since acetylene is only an intermediate in the pyrolysis, it is very important to remove it from the reactor quickly. The residence time of the hydrocarbon feed in the reactor must be kept below 0.01 sec, which was ensured by 150 m/sec gas velocity. The maximum temperature in the reaction zone was 1450°C and the pressure slightly above atmospheric. Oxygen and the hydrocarbon feed were first preheated to 350-450°C, then mixed in a tubular mixer; their ratio was fixed by automatic control for each experiment and was between 0.72 and 0.62. The average yield of acetylene was 6.9 per cent and the tar formed 3 per cent, which was cleared out from the reactor at 30-minute intervals with no interruption of the production, but somehow upsetting the pressure conditions. Each production test lasted about 480 hr; 10 tests were reported. Plant diagram of the process and details of the burner heads are given. 6 refs.

YA. S. KAZARNOVSKII, *et al. Khim. Prom.*, 1961, **1**, 11-15.

Design and Mass Transfer Study for New Multistage Fluidization Reactor

Multistage fluidization reactors equipped with downcomers for downward transport of solids are unstable in operation. A method was developed utilizing vibration to "shake down" the fluidized material through a plate consisting of large, non-fluidized, spherical beads and a support screen. This 150-page report describes how the preliminary plate design was improved, and how design and mass transfer data were correlated by means of experiments on a three-stage 6-in.-diameter column.

K. D. WILLIAMSON, JR., Argonne National Laboratory, Illinois, Report No. ANL-6267.

Cooling with Liquid Metals

The author discusses the properties and advantages of liquid metals, the corrosion problems to which they give rise, and the selection of materials of construction. He then considers the problems of purification and control of oxygen content, with particular reference to sodium and sodium-potassium alloys. 27 refs.

R. DARRAS, *Énergie. Nuc.*, 1961, **3** (2), 128-38.

Designing Temperature-stable Tubular Reactors

A slight change in tubular reactor conditions may cause uncontrolled temperature rise in exothermic reactions. The author shows how to prevent such conditions by designing the reactor and its control system for nearly isothermal conditions, with adequate safeguards against runaway temperatures. 13 refs.

P. HARRIATT, *Chem. Eng.*, 1961, **68** (10), 165-70.

Recovering Uranium Submarine Reactor Fuels

This illustrated paper describes how equipment for a fluoride volatility pilot plant has been modified to recover uranium from spent zirconium-uranium nuclear submarine fuel elements by a fused salt fluoride volatility process. 7 refs.

R. P. MILFORD *et al.*, *Ind. Eng. Chem.*, 1961, **53** (5), 357-62.

Aqueous Transport of Settling Slurries

A new correlation is presented for predicting a minimum design velocity for the aqueous transport of settling slurries. It is based on published experimental data.

G. A. HUGHMARK, *Ind. Eng. Chem.*, 1961, **53** (5), 389-90.

Flow of Fluids Review

Flow of fluids is reviewed with reference to single-phase flow, metering and controls, multi-phase flow, piping and pumps. 47 refs.

M. WEINTRAUB, *Ind. Eng. Chem.*, 1961, **53** (5), 405-8.

Gas Residence Times in Fluidized Beds

The authors describe a radioactive tracer technique which was developed for systems with an average residence time near 1 sec. 6 refs.

A. R. HUNTLEY *et al.*, *Ind. Eng. Chem.*, 1961, **53** (5), 381-3.

Calculating Parameters of Coal Mills

No reliable formula exists which expresses the relationship between the grindability of coals and the power requirements of mills. Grindability numbers are therefore of little use to designers of new installations.

This article presents calculating schemes for tubular, hammer and fan mills. Calculations are separated into thermal and technological sections.

M. PROKS, *Strojirenství*, 1961, **11** (5), 351-4.

Analyse Material and Heat Balances for Continuous Distillation

Relationships are presented to calculate the performance of existing equipment or to estimate the number of theoretical trays necessary to effect a given separation.

J. COATES and B. S. PRESSBURG, *Chem. Eng.*, 1961, **68** (4), 145-50.

Nomograph for Reaction Time or Reactor Size

This nomograph will rapidly estimate either the time required for a reaction in a given tubular flow reactor, or the reactor volume needed when the retention time for completion is known. Two examples illustrate the use of the nomograph: (1) The residence time is found to be 3-4 min for a feed rate of 50 lb/min, spec. vol. of feed 0.12 cu ft/lb, and a tubular reactor volume 20 cu ft. (2) The reactor volume is found to be 0.54 cu ft for a feed rate of 0.6 lb/min, spec. vol. of feed 9.0 cu ft/lb and a reaction time of 0.1 min.

H. B. KENDALL, *Chem. Eng.*, 1961 **68** (4), 168-70.

Heat and Flow Investigations on Finned Tube Bundles Subject to Transverse Flow—Part I

Heat transfer and resistance have been measured in 15 finned-tube bundles having different tube shape and arrangement, and subject to transverse flow. At 11 atm smooth and finned tubes confirmed the similarity theory well and formulæ from similarity values can be safely used for gases and liquids. Experimental measurements have extended the range of application of known equations for the heat transfer to bundles of smooth tubes to N_{Re} of 150,000.

H. BRAUER, *Chemie Ing. Tech.*, 1961, **33**, (5), 327-34.

An Exergy-entropy Diagram for Air

The capacity for doing work or exergy makes possible the assessment of the completeness of energy conversion in thermodynamic processes. Such calculations are simplified with diagrams of state with exergy as one co-ordinate. The author presents a newly calculated exergy-entropy diagram for air, and illustrates its use with the Linde process of air liquefaction. 10 refs.

H. D. BACHR, *Chemie Ing. Tech.*, 1961, **33** (5), 335-8.

GROUP G — MISCELLANEOUS

Protection of Refractories Against Erosion by Molten Glass

A method is described whereby platinum, in the form of a smooth, continuous coating, is mechanically keyed into the porosity of the refractory surface. Heavy coatings may be applied in critical areas subject to severe erosion. The technique is at present a two-stage process: the surface is first metallized with Pt by painting a liquid platinum compound on it and firing at 500-800°C to decompose the compound to yield Pt. This surface layer is then built up with a Pt-paste which is fired at over 1000°C. The final surface is smoothed and refired to 1000° C.

P. E. GAINSBURY, *Engelhard Ind. Tech. Bull.*, 1961, **1** (4), 136-8.

Nuclear Energy and Operational Research

The author stressed the contribution that operational research can make towards solving problems in connection with nuclear reactor structure and programming to produce energy at the lowest cost. He briefly analysed the five papers presented at the nuclear session of the conference. These papers covered management efficiency and economics, long-term nuclear energy programmes and the cost of such programmes. The author concluded that operational research offered great possibilities in the nuclear energy field.

J. GAUSSENS, *Énergie Nuc.*, 1961, 3 (2), 110-16. Second International Conference on Operational Research, Aix-en-Provence, September, 1960.

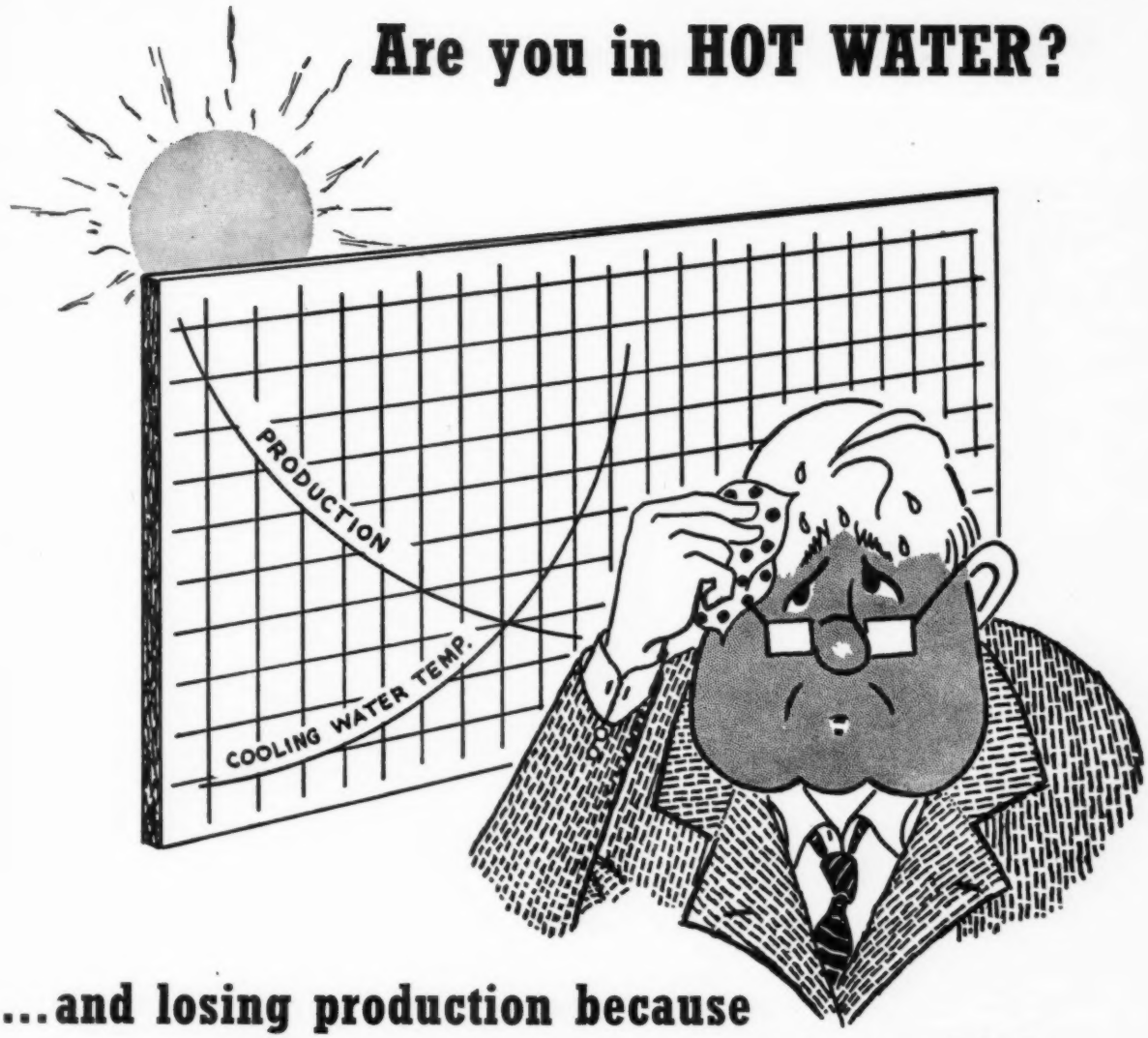
Solubility of SO_2 in Ammonium Bisulphite

This nomograph correlates SO_2 vapour pressure vs. true free SO_2 concentration in the temperature range 0-50°C.

R. A. BONSAL, *Chem. Eng.*, 1961, **68** (10), 182-3.

Brit. Chem. Eng. Abstracts: **FOLIO No. 20**

Are you in HOT WATER?



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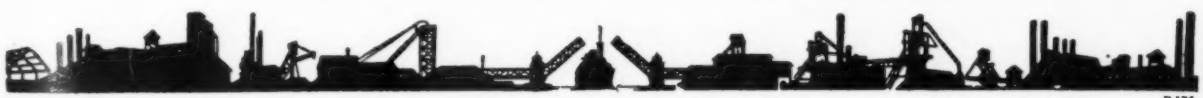

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Abstracts

GROUP G — MISCELLANEOUS (contd.)

Evaluating Quantity Discounts

The author shows how to calculate the cost of money tied up in larger inventories to determine the economics of quantity discounts. A nomograph is included.

G. E. MAPSTONE, *Chem. Eng.*, 1961, **68** (5), 117-20.

Carbon and Graphite—Materials of Construction Review

A review of the latest developments of carbon and graphite as materials of construction. 40 refs.

N. J. JOHNSON, *Ind. Eng. Chem.*, 1961, **53** (5), 413-16.

Protective Coatings for Refractory Metals*

Various ceramic coating systems for tungsten metal were developed and evaluated. These included silicide coatings, ceramic crystals in a glass matrix, zirconia-clad coatings, vapour-depositied SiO, and recrystallizing glasses. The system considered protective for tungsten at temperatures of 3000°F or higher, from a practical viewpoint, was a coating consisting of 35 per cent glass and 65 per cent zircon.

Tungsten wire specimens coated with this glass-zircon coating were protected for 10 hr at 3000°F. A study of the nature of the degradation of this coating tested at 3000°F as a function of time was carried out based on microstructural observations and X-ray diffraction analysis of the reaction products.

C. G. BERGERON *et al.*, 45 pp. Project 7350: Task 73500 Wadc TR 59-526 (Pt. II). Contract AF 33 (616)-5734. University of Illinois, Department of Ceramic Engineering, Urbana, Illinois.

A New Continuous Method for Preparing Aniline From Nitrobenzene by Béchamp's Reduction Method

This process has been developed using a liquid fluidized bed of Fe particles induced by upward-flowing liquid reaction mixtures. Rate data obtained from a small-scale continuous apparatus were higher than those obtained by batch reduction. The new continuous process will produce aniline of 99-99.9 per cent purity industrially. 8 refs.

S. YAGI *et al.*, *Chem. Eng., Japan*, 1961, **25** (1), 12-17.

A Study of Ternary Ion Exchange Reactions: Height of Exchange Zone and Ion Separation.

Mixed solutions of Na and Ca ion were passed through the resin bed of a strongly acidic H-form cation exchanger and the heights of exchange zones were measured for these salts.

Equations were then derived for the following: (a) the degree of Na ion separation, S; (b) the separation efficiency, η; and (c) the minimum height, Z_m, of resin bed capable of separating Na ion. 7 refs.

T. MATSUDA *et al.*, *Chem. Eng., Japan*, 1961, **25** (2), 104-8.

The Bottom Pressure of Powder Bed Packed in a Cylindrical Vessel

JANSSEN'S equation:

$$p = \frac{\gamma D}{4\mu_w k}\left(1 - \exp\left(\frac{-4\mu_w k h}{D}\right)\right)$$

denotes the vertical pressure of powders in columns. This paper discusses the many factors which affect the vertical pressure of non-cohesive granular materials packed in a cylindrical vessel.

The measured values of the powder pressure differ according to the state of the packing: whether packing is static or just beginning to slide down a vessel, whether loosely or closely packed. JANSSEN'S equation may therefore be used only to estimate the vertical pressure.

The authors have concluded that (a) JANSSEN'S equation should be expressed as:

$$p = \frac{\gamma D}{4\mu_w \alpha k}\left(1 - \exp\left(\frac{-4\mu_w k h}{D}\right)\right)$$

where α is a function of the material, of the cylinder diameter, of the state of the packing and of the method of measuring. With sand the state of the packing has a great effect, with millet and rape α varies with the diameter of the vessel; (b) values obtained by the balance method are useful for problems related to granular material flowing through the bottom of vessels. Values obtained by the gauge method are useful for calculating the strength of the vessel and the particles. Nomenclature: D is diameter of cylinder, h is depth of powder bed, p is vertical pressure of bed, γ is wt/unit vol. of powdered bed, all in c.g.s., k is ratio of horizontal and vertical pressures, μ_w is friction coefficient and $C = \mu_w k$.

R. ACKI and Y. MORI, *Chem. Eng., Japan*, 1960, **24** (12), 926-34.

* Author's abstract.

Methods of Comparative Calculation of Physico-chemical Properties

Unknown physico-chemical properties and data can be found by experiments, theoretical deductions and empirical or semi-empirical correlations. The article considers this last method and, as is evident from the number of references, the author attempted to give a thorough survey of the available literature concerning the methods of comparative calculation and its results. Most of the quoted references are in Russian. These calculations were based on linear and logarithmic correlations and were presented in subgroups. (1) Comparison of the values of a given property in two series of similar substances, e.g. entropies of homologue series. (2) Comparison of the values of two characteristics in a series of similar substances, e.g. correlation between the heat of dissociation and dissociation temperature for the carbonates of bivalent metals. (3) Comparison of the values of a given property in a series of substances at two different parameter conditions, e.g. dielectric constants of similar compounds at two different temperatures. (4) Comparison of the values of a given property of two substances at identical parameter conditions, e.g. surface tensions of two compounds at constant temperature. (5) Comparison of the values of two characteristics of one material at constant parameter, e.g. dielectric permeability vs. the activity coefficient of the solvent at constant concentration. 78 refs.

M. KH. KARAPETYANTS, *Khim. Prom.*, 1961, **1**, 33-42.

Protective Coatings Futures

Five papers were presented at the 15th Divisional Conference of the Protective Coatings Division of the Chemical Institute of Canada in February, 1961. Subjects discussed were: (a) perchlorovinyl enamels; (b) diffusion through vinyl polymers; (c) catalysis of polyurethane films; (d) fatty vinyl ether copolymers; (e) elastomers.

Chem. in Canada, 1961, **13** (4), 27-39.

Fine Grinding of Chocolate

Chocolate masses are generally ground in rolling mills. The authors have developed two equations, relating to the hydrodynamic and static processes taking place in the gap between the rolls, which were used to investigate the problem theoretically.

Experimental determinations of grinding progress and throughput on a rolling mill, under various operating conditions, have shown that these theoretically derived equations do not adequately describe the grinding of chocolate masses.

Other equations, which were derived from the experimental results, can predict the effect of changes in operating conditions on the throughput and the grinding.

G. RUISINGER *et al.*, *Chemie Ing. Tech.*, 1961, **33** (5), 319-26.

Second Status Report on Fuel Cells

This 76-page report covers recent literature, government and private programmes on fuel cell R & D.

B. R. STEIN and E. M. COHN, U.S. Army Research Office, Washington, 25, D.C. A.R.O. Report No. 2.

Summaries of Fuels and Materials Development Programmes

This report summarizes the objectives of some 100 projects supported by the Fuels and Materials Development Branch, Nuclear Technology, Division of Reactor Development. These projects were conducted at the Commission's laboratories, industrial, university and other laboratories during January 1960.

U.S.A.E.C. Report TID-6506.

Recent Metallic Packings

The technological properties of the Perfo ring are reported and compared with those of the Raschig and Pall rings.

R. BRAUN, *Chemie Ing. Tech.*, 1961, **33** (5), 350-2.

Method for Rating Heat Baffled Exchangers

This method is a simplification of the Tinker method, which is considered the most rigorous analytical approach to this problem. 19 refs.

A. DEVORE, *C.E.P.*, 1961, **40** (5), 221-33.

Find Reaction Equilibrium Graphically

Charts are provided which can simplify the selection of optimum reaction conditions and yields.

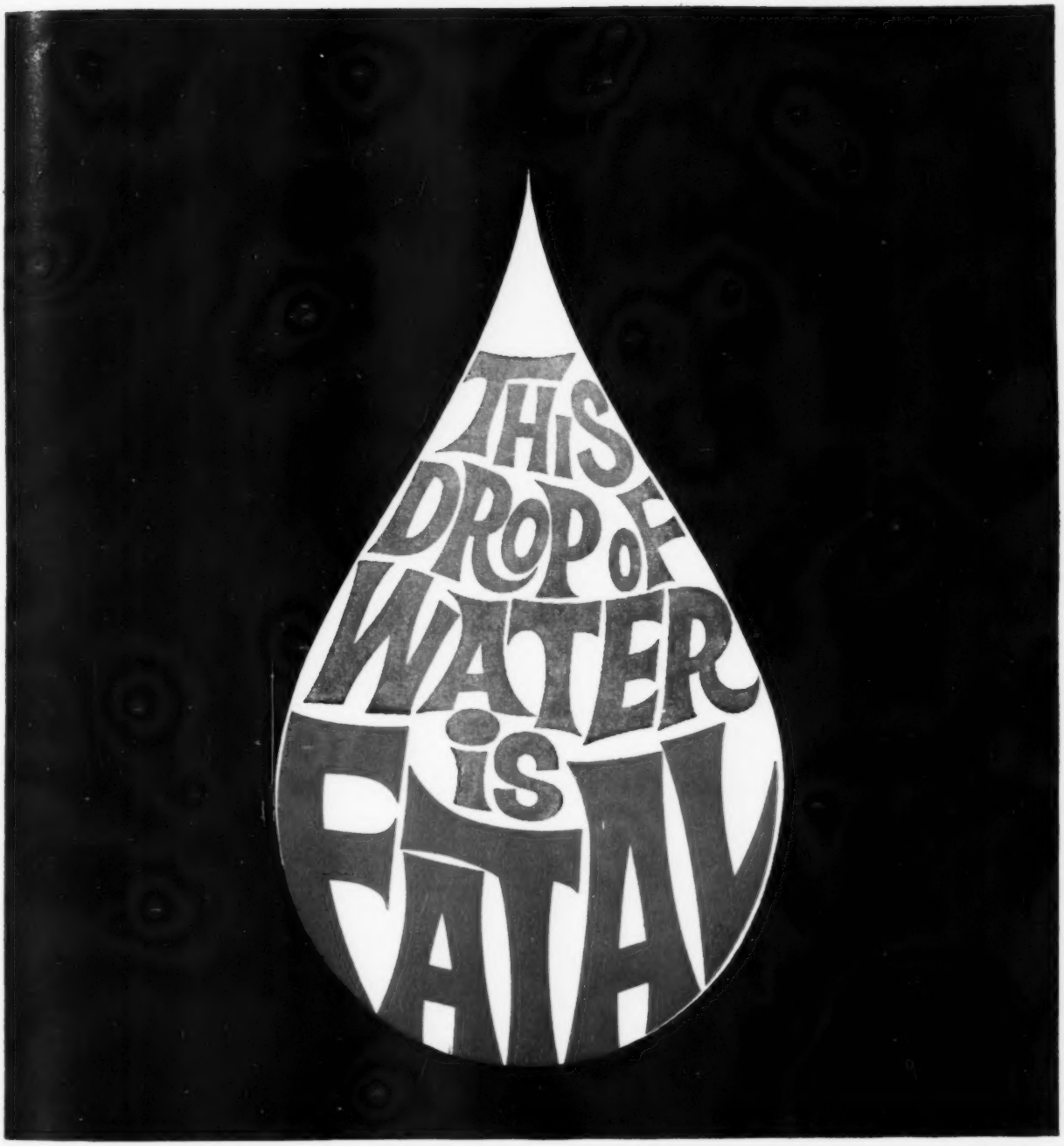
T. D. MCMINN, JR., *C.E.P.*, 1961, **40** (5), 251-6.

Centrifugal Pump Selection

The author uses several graphs to show how, when a specified head and capacity are required, the most economic values of the following pump characteristics can be found: rpm, number of impellers, double or single suction, efficiency, power consumption, minimum net positive suction head.

R. H. MEIJER, *C.E.P.*, 1961, **40** (5), 217-20.

Brit. Chem. Eng. Abstracts: **FOLIO No. 21**



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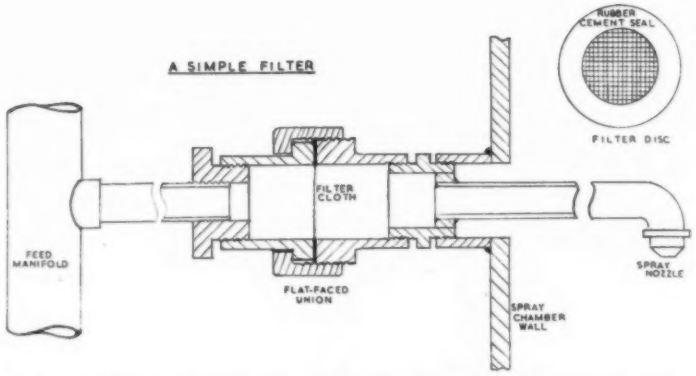
AP63

A Simple Filter Fitting



WHEN using spray nozzles, one frequently meets the problem of blockage, particularly in such cases as intermittent operation or the use of recycle liquid from a process.

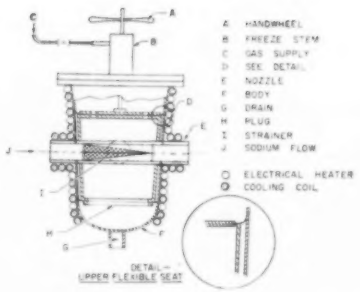
These conditions were experienced with a water spray washer which was being operated intermittently. It was found that the build up of impurities in the feed lines (e.g., pipe scale) caused nozzle blockage very frequently. The blockages entailed dismantling of the nozzles for cleaning, with consequent delay in operation. The problem was overcome by installing simple filters in the feed lines to each spray nozzle. Normally the individual lines were attached to the feed manifold by means of pipe unions. These were replaced by larger flat-faced unions with a disc of filtering medium (e.g., 100 mesh stainless-steel cloth) clamped between the faces as shown in the diagram. A good permanent seal was obtained with the wire filter disc by smearing with rubber cement and allowing to dry before fitting. The filters proved very effective, and, as the filter cloth could be removed, cleaned and replaced quickly, delays were much smaller than those encountered previously by having to dismantle the whole spray system. W.H.N. and G.O.D.

Stop-valve Strainer for Liquid Metal Systems

AN in-line strainer, capable of being easily removed, cleaned and replaced, was needed for liquid metal coolant systems. In the past for the clean-up of sodium systems both in-line and by-pass strainers had been used. To service an in-line strainer it is necessary to drain the system of all sodium; to service a by-pass line strainer, valves are required to isolate the strainer. Both arrangements suffer from the disadvantage of lengthy removal and replacement operations.

A new device providing a removable strainer in combination with a plug-type blocking valve was designed. It was built in a 3-in. pipe size.

The valve strainer resembles a lift-plug valve, consisting primarily of a tapered plug in a fixed body with the strainer element positioned in the normal flow passage in the plug. The device differs from a plug valve in several respects: (1) an access port is built into the body at 90° to the flow line to permit strainer removal; (2) the centre of the plug is hollow to reduce its mass; and (3) the body has a drain connection. The access port is sealed with a blind flange joint. The bonnet and yoke assembly has a water-cooled stem freeze seal, a lifting screw for raising and lowering the plug, and a hand wheel for rotating the plug. The plug was fitted with flexible seals at both top and bottom to inhibit leakage from the annulus area. The strainer element is stainless-steel wire mesh with openings of 0.005 in. The assembly is shown in the diagram.



Removal of the strainer element from the valve body requires solidification of sodium in the annulus between the plug and body. Subsequent to cleaning and replacement of the strainer, the sodium in the annulus must be melted before the valve can be rotated into the flow position. Stainless-steel tubing for cooling water and tubular resistance heaters were wrapped around the body and nozzles of the unit to accomplish this heating and cooling function. The cooling coils were arranged with separate flow circuits for the body and the nozzles.

For removal of the strainer element, starting with both the strainer and the valve in the normal operating position, the following sequence of operations must be followed.

(1) Raise the plug and rotate it through 90° into the blocking position; this rotation aligns the flow passage with the access port; then reseat the plug.

(2) Admit water to the cooling coils; continue circulation until the temperature of sodium in the plug-body annulus is less than 200°F.

(3) Open gas supply to valve body and open drain valve to flush out sodium from the plug cavity.

(4) Close the gas supply valve and then close the drain valve.

(5) Open the access port, introduce an inert gas purge, and remove the strainer. (While strainer is being cleaned, replace the access port closure.)

(6) Replace clean strainer in the plug, reversing the operations of Step 5.

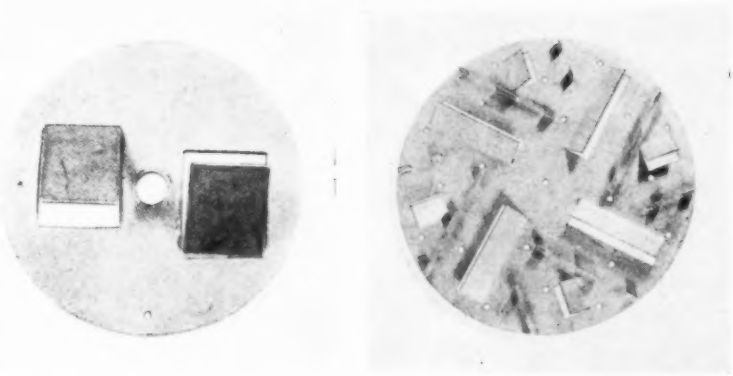
(7) Turn off cooling water and turn on electric heaters. Continue heating until sodium in the annulus has reached a temperature within 100°F of the bulk sodium temperature.

(8) Raise plug, rotate it back to the flow position, and reseat.

The frequency of strainer removal and cleaning depends upon the quantity of contaminants in the particular loop being cleaned. When it has been determined that the system is sufficiently clean, the strainer may be removed and the device may be used as a blocking valve.

(Based upon a report of Atomics International Inc. Division of North American Aviation Inc. No. NAA-SR 5241.)

Redistributors for Pulsed Columns



CHANNELLING is one of the difficulties which may be encountered with pulse extraction columns, particularly with systems where the density of the continuous phase is appreciably higher at the top of the column, the major indication of its occurrence being a marked increase in the apparent H.T.U. values achieved in the column.

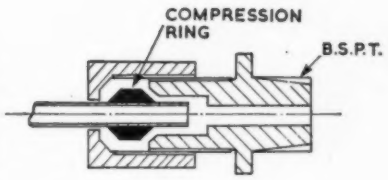
It can be reduced and its effects minimized by the use of redistribution devices which may be fitted in a column at 3 to 4-ft intervals. An effective design of redistributor is the louvre plate, two examples of which are shown here. The smaller is for a 3-in. column, whereas the larger has proved successful in 34-in. diameter columns. The free area provided is approximately 25 per cent.

Abstracted from "Design and Operation of Purer Process Pulse Columns", Report HW-SA-2083. Hanford Atomics Products Operation.

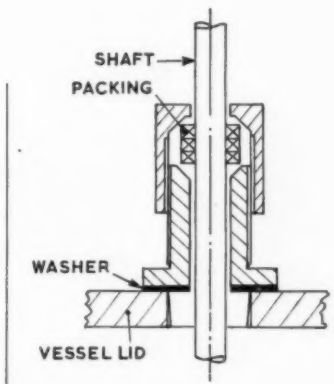
Agitator Shaft Seal

DURING construction of a small (5-gal. capacity) pilot-plant reactor, the question arose of how to provide a gland around the vertical, centrally mounted agitator shaft to prevent leakage at that point. The reaction was to be carried out at atmospheric pressure, but at a temperature very near the boiling point of the reactants.

A compression fitting of the type commonly used for connecting small-bore tube to larger pipes or vessels was drilled out to a diameter about $\frac{1}{32}$ in. larger than the diameter of the shaft, the compression ring replaced by packing, and the connector mounted as shown in the sketch to provide an efficient, easily made, stuffing box.



(a) COMPRESSION JOINT NORMAL USE

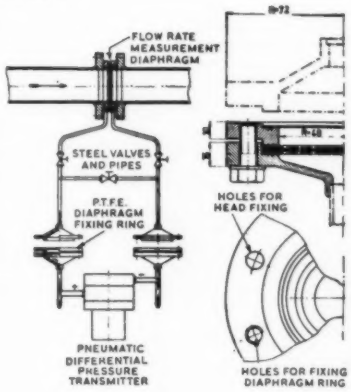


(b) ADAPTED FOR USE AS STUFFING BOX

Metering Hydrofluoric Acid

AMONG some recently-described fluorination techniques* evolved for reprocessing and decontaminating spent nuclear fuels was a conventional orifice plate method of flow measurement adapted for metering the flow of gaseous HF. In order to protect the pneumatic differential pressure transmitter from the action of the acid, two diaphragm chambers were fitted between the transmitter and the upstream and downstream connections at the orifice plate. The diaphragms were made of P.T.F.E., likewise the orifice plate itself.

* CAMOZZO, G., and PIZZINI, S. *Energia Nucleare*, 1960, 7 (12), 849.


FLOW RATE MEASUREMENT DIAPHRAGM
STEEL VALVES AND PIPES
P.T.F.E. DIAPHRAGM FIXING RING
PNEUMATIC DIFFERENTIAL PRESSURE TRANSMITTER
HOLES FOR HEAD FIXING
HOLES FOR FIXING DIAPHRAGM RING

Improvement to Spray Cooler

AT A SULPHURIC ACID plant where spray-type coolers were used the coolers consisted of banks of 3-in.-diameter cast iron tubes made by normal casting methods. With these tubes repairs and replacements were frequent; thus rings were continually being fitted and new tubes installed. With the replacement of the tubes by 4-in.-diameter centrifugally cast c.i. tubes, the repair operations were reduced considerably and during one year's service one ring only required to be fitted to a single tube of the spray cooler.

A.R.

Contributions Invited

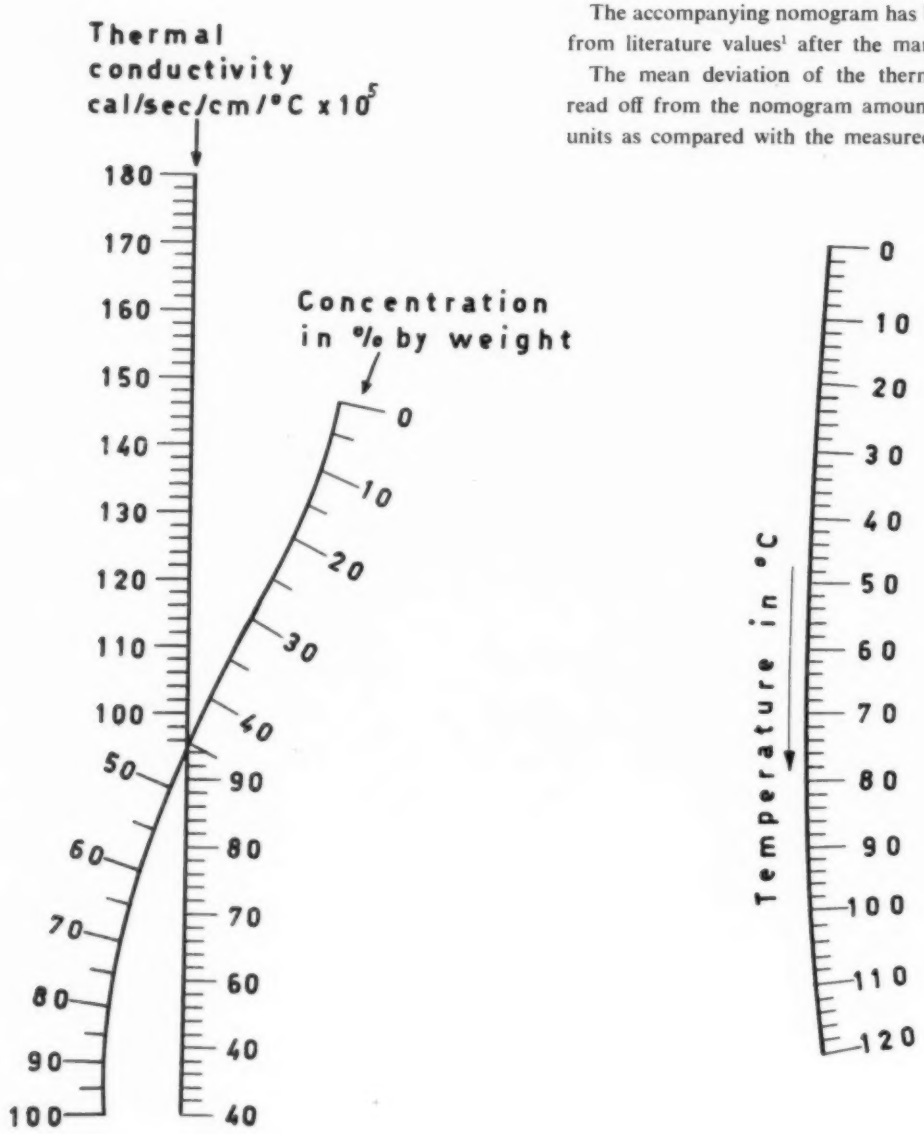
The Editor invites contributions to "Process Engineer's Notebook". They should preferably deal with practical devices designed to overcome problems for which standardized equipment is not available; hints for the improved design of conventional equipment; methods of improving equipment operation; safety devices; etc. For the most meritorious contribution the sum of **10 gns.** will be paid, while other contributors will receive **5 gns.** They will be published anonymously or under the contributor's name, according to his wishes.

THERMAL CONDUCTIVITY OF AQUEOUS PROPYLENE GLYCOL SOLUTIONS

by A. M. P. TANS
Staatsmijnen in Limburg, Geleen, Netherlands

The accompanying nomogram has been constructed from literature values[1] after the manner of Lo-Ho.[2]

The mean deviation of the thermal conductivity read off from the nomogram amounts to 0.5×10^{-5} units as compared with the measured values.



LITERATURE CITED
[1] CURME, G. O., and JOHNSTON, F. "Glycols", Reinhold Publ. Corp., New York, 1959.
[2] Lo-Ho. *J. Franklin Inst.*, 1948, **245**, 227-44, March.

British Chemical Engineering
NOMOGRAM NO. 60

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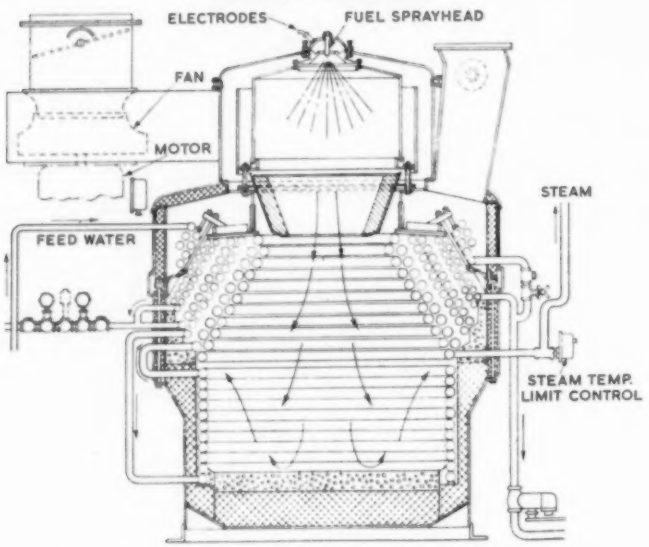
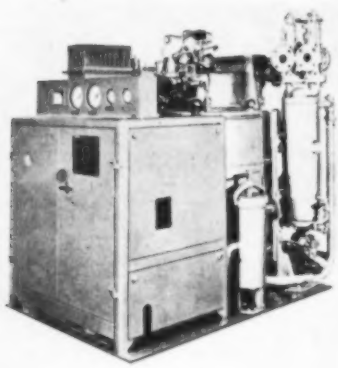
PLANT EQUIPMENT NEWS

Package Steam Power



The Stone-Vapor boiler, now manufactured under licence in this country, is about one-quarter the weight and one-fifth the size of conventional boilers of the same rating. In just two minutes, from a cold start, it can develop 200 psi steam pressure. Operating pressures are available from 50 to 300 psi or up to 600 psi on high-pressure units. There are four main sizes with evaporation rates (in lb steam/hr at 212°F) of 1202, 2105, 3310 and 5420 respectively. The basic price exclusive of installation costs, which are a fraction of the usual, are £1985, £2580, £3400 and £4700 for the four sizes quoted above. Boilers may be oil fired or gas fired, and in some cases a combination of both. Special models for pressures up to 1000 psi and also superheaters for steam temperatures up to 1200°F are available. Among the claims for this boiler are low capital cost, low installation cost, space and labour saving, fuel saving, simple operation and maintenance and safety—although 20,000 of these units are in use, no explosion has ever been recorded. Normal output is 1000 to 4500 lb of steam/hr from single units, larger amounts being provided by multiple units. **J. Stone & Co. (Deptford) Ltd., Arklow Road, London, S.E.14.**



BCE 7 for further information

Flow Transmitter

Models 11 and 11A measure the differential pressure produced by a venturi tube or orifice plate and transmit a 3-15 psi high volume signal, which is exactly proportional to the input. The D/P unit uses rupture-proof stainless-steel bellows, whose motion is transmitted through a frictionless torque tube to the local mechanical indicator and to the linear pressure transmitter. The D/P unit has adjustable damping, is completely proof against accidental overloads and is maintenance free. No mercury is used and the instrument can be supplied with all wetted parts in stainless steel. **AEI Ltd., Instrumentation Division, Process Control Department, P.O. Box 1, Harlow, Essex.**

BCE 8 for further information

Low Head Cooling Towers

These are specially designed for small industrial duties including air conditioning and refrigeration. They incorporate a rugged mechanism and non-corrosive components, including Polygrid polystyrene packing, and are designed on the counterflow principle which allows most efficient contact between water and air.

Series 2. Cooling towers are induced-draught, horizontal air flow units designed to meet lower-profile requirements. Maximum height is 8 ft and standard single cells can be offered ranging from 60-300 tons. Combination of standard cells may be used to meet greater cooling requirements.

Series 3. Cooling towers are low profile induced-draught units designed for intermediate cooling capacities using standard cell selections. HWP offer standard single-cell installations ranging from 60-650 tons.

Series 4. Towers are designed for small duties. Single-cell models up to 900 tons and multi-cell arrangements to meet any requirements are available. **Head Wrightson Process Ltd., 20/24 Old Street, London, E.C.1.**

BCE 9 for further information

Low-flow Controllers

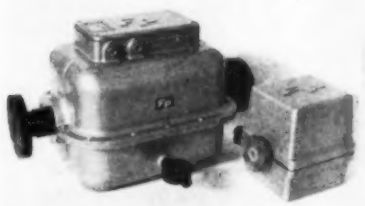
A range of controllers has been introduced which will automatically regulate flows as low as 1-47 scc/min of gas or 0.18 cc/min of liquid.

Two types are available: one maintains a constant flow of fluid through an external needle valve, irrespective of downstream pressure variations; the other is for use when the downstream pressure is constant. Both are available in brass (suitable up to 250 psi and 180°F) and steel (rated at 500 psi and 250-390°F). **AEI Ltd., Instrumentation Division, Process Control Department, P.O. Box 1, Harlow, Essex.**

BCE 10 for further information

Low-conductivity Electro-magnetic Flow Meter

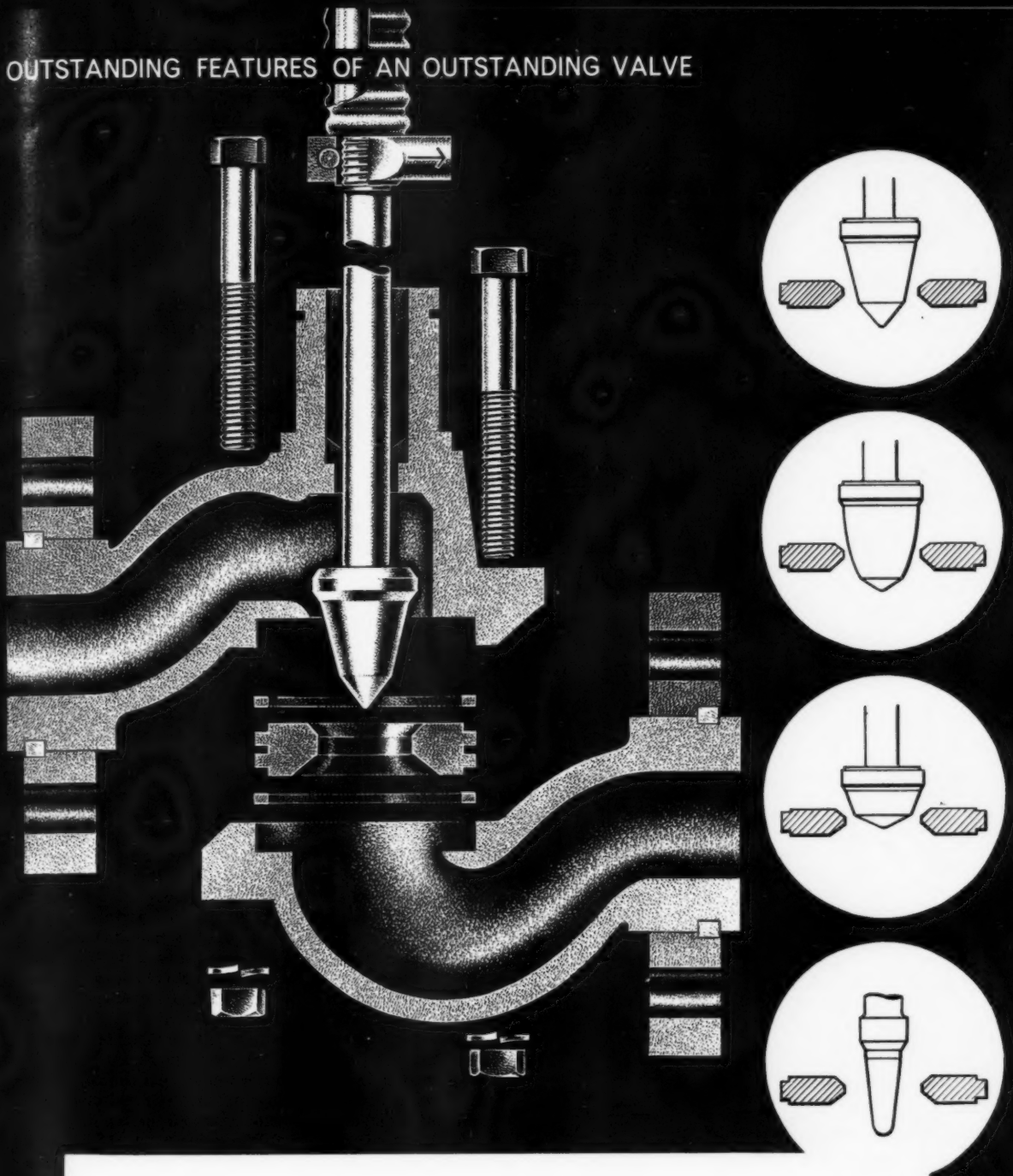
A new low-conductivity electro-magnetic flow meter system has been developed, which extends the range of applications on which this type of flow meter may be used. It will handle liquids and slurries with a conductivity as low as 0.1 micromhos/cm. This means that the rate of flow of fluids not far removed from pure hydrocarbons can now be accurately determined by this magnetic meter.



Fibreglass or P.T.F.E.-lined tubes can be supplied. **Fischer & Porter Ltd., Workington, Cumberland.**

BCE 11 for further information

OUTSTANDING FEATURES OF AN OUTSTANDING VALVE



SPLIT BODY CONSTRUCTION

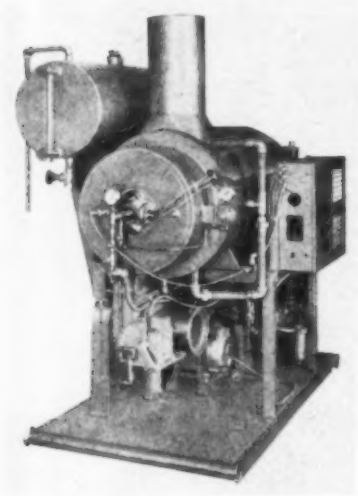
and the quick change trim feature of Audco Annin Control Valves greatly reduce the time and money spent on maintenance — thereby ensuring maximum plant efficiency. These features, plus accurate control and positive shut-off, mean long and trouble-free service. Valves are available in a wide range of sizes and materials. Further details supplied on request.

GLOUCESTER CONTROLS LIMITED
AUDCO ANNIN DIVISION

EASTERN AVENUE, GLOUCESTER TEL: GLOUCESTER 21451

PLANT EQUIPMENT NEWS

Liquid Phase Heater



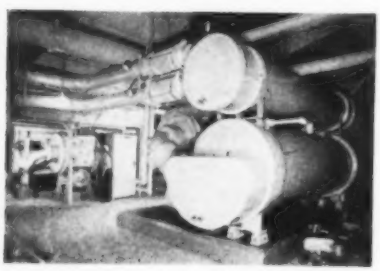
This is a forced-circulation, coiled-tube-type, direct-fired heater that exploits to the full the advantages of the heat-transfer oil systems. Fully packaged, it modulates automatically over the entire firing range, maintaining maximum combustion efficiency at all times, and provides higher temperatures at lower cost. Simple adjustment of a temperature limit control regulates the fuel supply to the combustion chamber as needed to raise the heat-transfer oil medium to the predetermined temperature setting. Output oil temperatures up to 600°F can be achieved.

The pressurized combustion chamber releases about one million Btu per cu ft of combustion space per hour. This is over five times the heat released by other type heaters. The Hi-R-Temp heater illustrated is type 5425. It is 83 in. long, 36 in. wide and 65 in. high, and has a thermal capacity of 3,120,000 Btu/hr. It will be exhibited for the first time in this country at the International Plastics Exhibition. **J. Stone & Co. (Deptford) Ltd., Arklow Road, London, S.E.14.**

BCE 12 for further information

Centrifugal Water Chiller

The Centravac is the outstanding centrifugal liquid chiller for process systems. It incorporates a two-stage motor-driven centrifugal compressor and a shell and tube evaporator. It automatically starts, adjusts output with load variations and stops without manual attention.



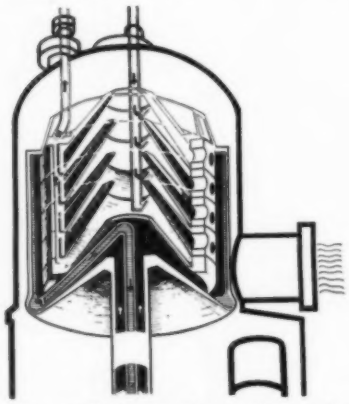
It is of completely hermetically-sealed construction and is available in a wide range of capacities. A single unit can be used on installations requiring capacities from 150 to 1700 tons of refrigeration. **Trane Ltd., 14-18 Heddon Street, London, W.1.**

BCE 13 for further information

Evaporators for Heat-sensitive Liquids

These evaporators, designed primarily for heat-labile liquids, consist of a stack of rotating hollow cone elements, supported on a hollow spindle, through which steam is supplied to the stainless steel walls forming steam jackets.

The liquid to be heated is sprayed on to the heated inner surfaces of the cone elements at their top edges, and is immediately spread in a thin layer over the entire surface. The time taken to cross the surface is about 1 sec.



The conditions at the heating surface are ideal for heat transfer and evaporation and this type of evaporator vaporizes a greater amount of water/unit area than a non-moving evaporator—and in a fraction of the time.

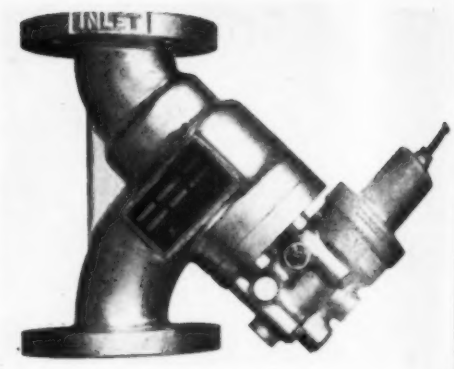
The concentrate from each cone element is gathered around the periphery of the cone element stack and is displaced upwards towards a paring tube which ducts it off. Evaporated vapours are led off under high vacuum through a large side outlet and the steam condensate is collected from the steam jacket by another paring tube.

This evaporator, the Centri-Therm, is marketed throughout the world by the Alfa-Laval Group. **Alfa-Laval Co. Ltd., Great West Road, Brentford, Middlesex.**

BCE 14 for further information

Brodie 500 Series Control Valves

This series of regulating valves with unit built integral pilot valves are designed for close regulation of upstream or downstream pressure, rate of flow and for many multiple purposes. A minimum of 10 psi pressure differential between inlet and outlet is required to operate pilot valves. Pressures from 10 to 300 psi can be controlled within ±1 per cent.



Rate of flow can be maintained within ±2 per cent without surging, chattering or pulsating. This series includes valves for back-pressure regulation (No. 560); pressure-reducing regulation (No. 550); pressure-reducing regulation with surge pilot (No. 551); and rate of flow control (No. 580). There is also a valve with pilot block (No. 501) and a differential pressure valve (No. 503). Size 2 in. to 12 in. **Gilbarco Ltd., 740 High Road, Tottenham, London, N.17.**

BCE 15 for further information

Automatic Control Valves

Control valves for hydraulic machinery, of a recently introduced range, are pneumatically operated through an integral diaphragm actuator. The pneumatic signal may be controlled either manually, electrically or mechanically. These valves are generally used for sequencing operations, frequently from an automatic timer. Pneumatic actuation has been adopted because it offers a larger life of both main line and pilot valves. The valves have mitre seats, give dead-tight shut-off, and are suitable for pressures up to 6000 psi.

Process control valves with either linear, logarithmic or on-off characteristics are also available for steam, liquids and gases. These valves are suitable for use with any standard controller. **Hunt & Mitton Ltd., P.O. Box 144, Oozells Street North, Birmingham, 1.**

BCE 16 for further information

Micrometer Dial

This unit has been designed to provide a quick and easy method of setting an angular displacement, to the nearest minute of an arc, on a variety of small electrical components such as synchros

SUPER-D-HYDRATOR

"Keep it under your sombrero, Señor"

"I have news from across the border, Señor, brought by my special messenger service on a Mexican Eagle. People are saying that Sharples not only make super centrifuges, but also provide a full consultative chemical engineering service on any separation project. I am a poor man Señor. I speak only the truth."

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P24A

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PLANT EQUIPMENT NEWS

and potentiometers, with a high degree of accuracy, in the order of ±15 seconds of an arc.

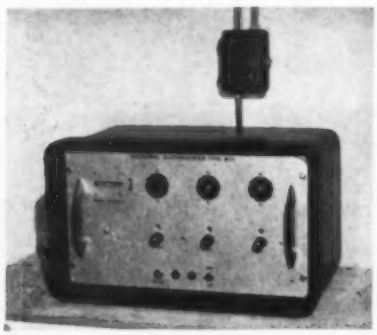
The micrometer principle is used, thus making the reading and setting far easier than is the case in the usual vernier-type dial.

The unit is readily adapted to mount in a gearbox for various applications. The main drive gear is designed in such a way that any wear on the teeth is automatically compensated, thus maintaining its accuracy. **Elliott Bros. (London) Ltd., Airport Works, Maidstone Road, Rochester, Kent.**

BCE 17 for further information

New Developments in Batchcounting

By the inclusion of the necessary stampings and fixing lugs, together with a comprehensive printed circuitry, it is now possible to take a "nearly" completed unit off the shelf and in a few minutes include the necessary component to meet the requirements of the stated application.



The front panel with its industrial air-tight-dust-tight enclosures is finished in a metallic grey and the batch number selector switches "click" positively into their new position when rotated and at the same time a circular disc, fixed to the switch knob spindle behind the panel, shows the selected batch number through an observation hole in the panel. A toggle-type re-set switch is also included, as also is an internal mains adjustment panel. The unit is made for rack, panel or case mounting to standard G.P.O. sizes.

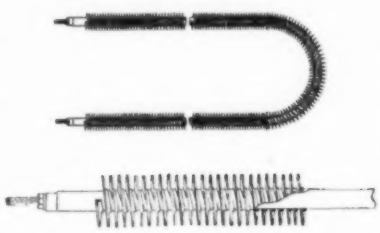
Design of circuitry is such that the unit can be easily modified to accommodate such applications as dual outputs, time delays, microswitch, photocell and magnetic pick-up input devices, speed of count being up to 20,000 per minute. **Electronic Machine Co. Ltd., Mayday Road, Thornton Heath, Surrey.**

BCE 18 for further information

Finned Electric Heating Elements

A new type of finned electric heating element with fins made from an "L" section is now available in lengths from 1-12 ft.

The fin is smooth and easily cleaned, and it is tightly coiled around the electric heating tube. Some examples of thermal output and element temperature are given in the table.



	Thermal Output	Element Temperature
Still Air	24 watts/in.	350°F
	100 watts/in.	700°F
Moving Air 350 fpm	70 watts/in.	250°F
	100 watts/in.	350°F

Electron (London) Ltd., Accrington Works, Strathmore Road, Croydon, Surrey.

BCE 19 for further information

Bascodur Valves for Corrosive Media

Bascodur is a thermosetting synthetic material which possesses corrosion resistance against chemical agents including acids, alkalis and solvents. It is recommended for use where these agents are encountered at elevated temperatures. Bascodur protective lining is applied on plug valves, globe valves, angle valves, low-pressure gate valves and sight flow glasses. These valves are now available in the U.K. through the sole agents: **I.V. Pressure Controllers Ltd., Atlas House, 683 London Road, Isleworth, Middlesex.**

BCE 20 for further information

New Reducing Valve

A high-pressure reducing valve, capable of an extremely fast response rate with a high degree of stability under the most difficult conditions, has been manufactured.

Known as the PAS.227, it is designed to accept an inlet pressure of 4000 psi maximum, which can be applied to the valve (open unpressurized) in 2 milliseconds. It has an inlet pressure range from 500-4000 psi, while the outlet pressure is 400 ±25 psi over a flow range from 5-65 cfm.

The downstream system which the PAS.227 supplies consists of a few cubic inches only as a result of the limitation of overshoot, and operation without oscillation, which was an essential requirement, presented an extremely difficult problem.

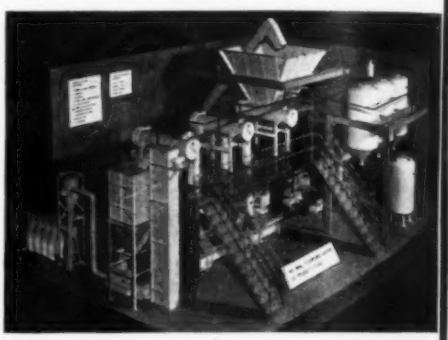
Now fully developed, the PAS.227 can accept an increase of pressure on the inlet side from zero to 4000 psi in 2 milliseconds, control the pressure in the downstream system, consisting of 8 in. of ¼ in. O.D. pipe plus 3 cu in. and stabilize in 0.2 sec. The total overshoot of pressure in the downstream system is less than 140 psi above control pressure.

The valve is designed to withstand periods of shelf life of up to five years and to operate consistently without servicing at any time during this period. It has a temperature range of −58°C to +110°C. Accelerations of up to 20 g can be applied in the most sensitive plane without affecting outlet pressure characteristics.

The PAS.227, which embodies an integral filter, is 4¾ in. long and has a diameter of 1½ in. It weighs approximately 1 lb. **Hymatic Engineering Co. Ltd., Redditch, Worcestershire.**

BCE 21 for further information

Animal By-products Plant



A model of a combined animal by-products plant, specially built for exhibition by IWEL Engineering on the Heenan Group's stand at the British Trade Fair in Moscow.

The model shows the layout of the entire plant from the entry of animal waste to the final products of tallow, meal and fats. The plant is designed for scientifically controlled, odourless processing. **Iwell Engineering Ltd., 7-11 Old Bailey, London, E.C.4.**

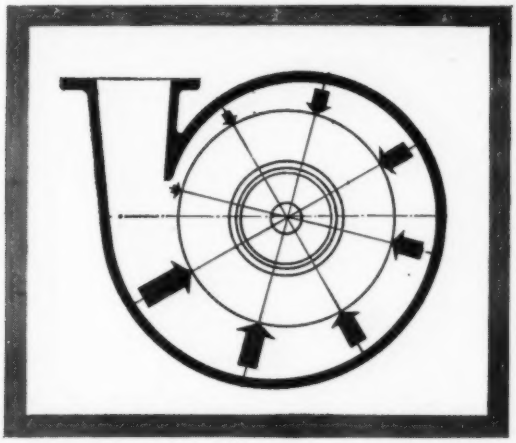
BCE 22 for further information

New Mixer Allows Extra Mobility and Adjustment

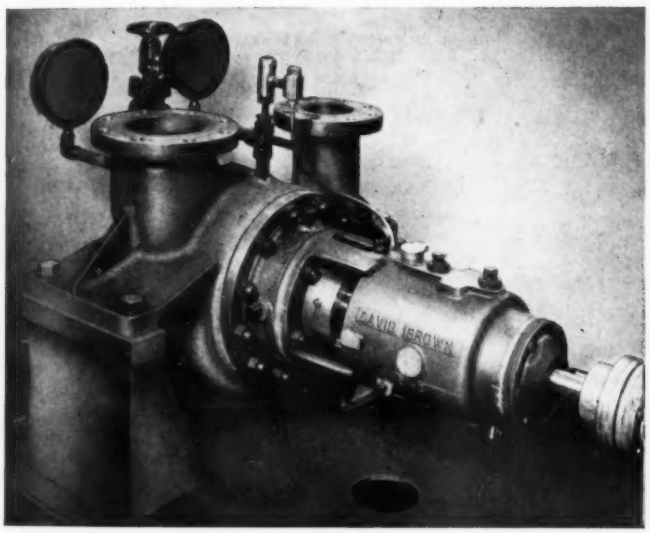
This new mobile and adjustable mixer is suitable for the mixing of liquids of all types including dyes, paints, foodstuffs, pharmaceutical products, waxes and oils. A stainless-steel shaft and propeller is fitted as standard, but these components can be supplied in other metals. The unit can be used in even the most awkward places.

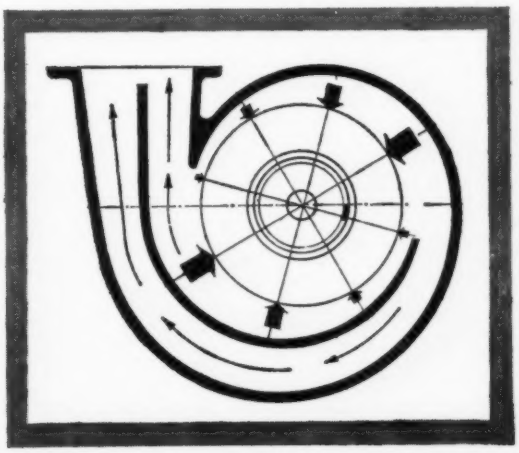
The mixer is mounted on ball-bearing castors, the base frame is fitted with adjustable stops, which can be used to lock the unit in a steady position, particu-

Why HYDRAULIC RADIAL BALANCE makes so much difference to the life of a centrifugal pump



See how the outdated single volute construction promotes uneven pressure around the periphery of the impeller, causing excessive bearing wear, excessive maintenance, excessive costs !





Double volute construction of David Brown 'Bingham' Pumps ensures equal pressures on opposite sides of impeller, giving hydraulic radial balance. Result—long life, infrequent maintenance.

'Bingham' double volute centrifugal pumps

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PLANT EQUIPMENT NEWS

larly where this is necessary to cope with uneven floors.

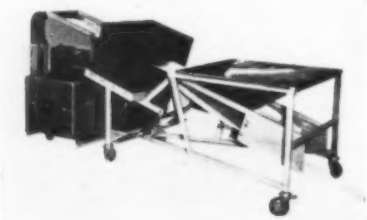
The unit can be powered with motors up to 5 hp and, in all cases, the motor and rotors are designed to be operated by "finger touch". A special keyed locking device prevents turning of the motor on the vertical shaft when operating. This particular model allows up to 2 ft vertical adjustment of the mixer, but can be modified to suit any type of drum. The unit can handle quantities from 2 to 25 gal at each mixing.

The cost of a standard mobile mixer with counter-balanced ½-hp motor and head giving finger-tip control is £120. **Chemical Equipment Engineering Ltd., Castle Street, Macclesfield.**

BCE 23 for further information

Conveyor for Bulk Powder

The need for a convenient method of inspecting bulk powdered material for tramp metal has increased recently due to the trend of introducing continuous-flow production lines. A light-duty conveyor to work in conjunction with the LOMA metal detector is now available.



The photograph shows a feed hopper which is situated such that it can be easily fed by a troughed food-quality rubber belt through the metal detector and on to the next process. On the detection of metal a signal is stored until the product reaches the end of the conveyor, when an automatic rejection chute operates and diverts the contaminated material into a reject container.

The conveyor is of tubular construction and has a stoved-enamel finish. Castors are provided so that the whole unit is portable. Variable-speed drives can be fitted, if required, as an extra. **Automa Engineering Ltd., Cherry Tree Rise, Buckhurst Hill, Essex.**

BCE 24 for further information

N.E.L. Vacuum Manometer

A new manometer has been developed at the National Engineering Laboratory. A bulb is blown at the top of the closed limb to provide expansion space for entrapped gas. An identical bulb is blown at the bottom of the open limb to receive the mercury which falls from the other bulb when the manometer is connected to vacuum. In order to minimize the "hammer" effect when the vacuum is suddenly released, a short length of small-bore capillary tube connects the two limbs.

The range covered is 0-300 mm/Hg and the reduction in error compared to a conventional U-tube manometer with the same volume of entrapped gas is from 17 mm/Hg error to 0.33 mm/Hg error at 300 mm/Hg. **N.G.N. Electrical Ltd., Accrington, Lancs.**

BCE 25 for further information

Liquid Level Alarm Switch Model 26

The AEI liquid level alarm switch model 26 features a patented flexible shaft with no pivots or rubbing parts, no packing glands or stuffing boxes, direct or reverse acting mechanism. It consists of a displacer mounted on a short displacer arm forming an extension to the flexible shaft, the fixed end of which is mounted on a standard flange. The switch is operated by the change in buoyancy of the displacer and not by the motion of the float riding on a changing liquid level. **AEI Ltd., Instrumentation Division, Process Control Department, P.O. Box 1, Harlow, Essex.**

BCE 26 for further information

Pipeline Control by Telemetry

Pipeline remote control equipment, which has been manufactured and supplied for several years to American oil, gas and chemical industries, is now available in the U.K.

This solid-state, printed-wiring equipment can give remote control by radio or land-line pair of pumps and valves, etc., at a number of unmanned stations. This is assisted by the central display and printer logging of alarms and variables such as pressures and flows, etc., measured by instruments at the stations. As two finished systems are very seldom alike, the equipment design is adaptable to meet a range of requirements. Systems also can be extended easily to provide extra facilities if additions are made to plant and/or instrumentation at a later date. The equipment can be serviced by non-technical personnel. **Rotax Ltd. (Process Control Group), Chase Road, London, N.W.10.**

BCE 27 for further information

Gardner "Airmix" Powder Mixer

The Airmix is a new, non-mechanical machine that mixes powders in less than 1 minute.

It consists of a cylindrical shell with a conical base, at the bottom of which is fitted the mixing head. The latter contains a series of special nozzles which are fed with compressed air from a compressor in 1 or 2-second blasts, with a few seconds' interval between each blast; thus a spiralling mixing action is imparted to the powder.

A number of important advantages arise from this particular design, quite apart from the extreme rapidity of mixing. First, there is a complete absence of working parts requiring maintenance or subject to wear. Second, the only power consumption is for the compression of air, and this, considered on the basis of

power per ton, is considerably less than the power required by mechanical mixers —in some cases the actual power requirements are one-tenth of those of mechanical machines employed for the same duties. Third, the size of a batch does not impose any limitation on the mixing efficiency. Fourth, feeding and discharging the machine is also carried out more rapidly than with many other types of mixer.

Airmix machines are made in a capacity range of from 2 to 800 cu ft. They can be modified to be used as a combined mixer and sprayer to enable liquids to be added and mixed with the powder. It is possible for liquids to be added to the extent of 40 per cent of the total weight of charge. **Wm. Gardner & Sons (Gloucester) Ltd., Bristol Road, Gloucester.**

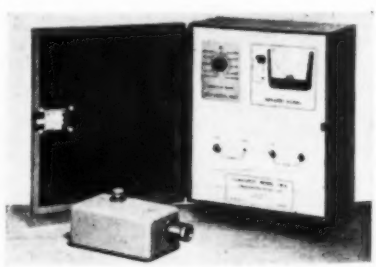
BCE 28 for further information

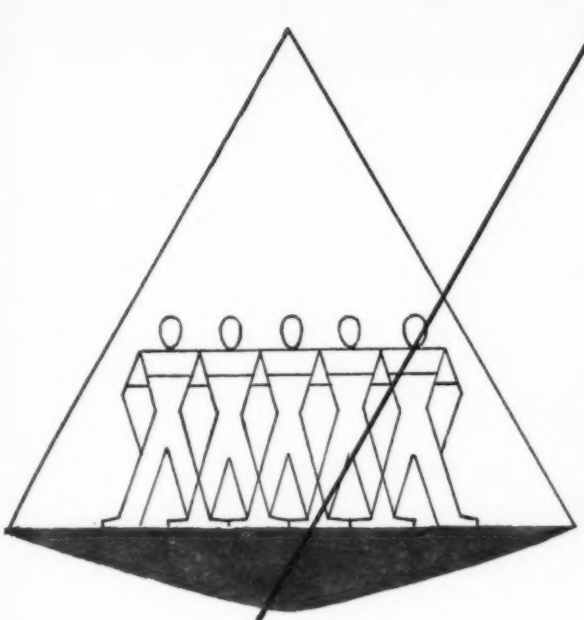
Responsive Radiation Thermometers

The principle of a new range of high-temperature thermometers is an infra-red detector which generates a signal voltage proportional to the radiation density.

With a research model (TD-1) transient phenomena of 10 microseconds in duration may be observed, measured and recorded. This instrument will function from 100°F and the industrial TD-3 from 180°F.

Infra-red scanning systems available from the supplier of these instruments can scan an extensive area and present a visual image of the observed temperature pattern without physical contact. The two types offered are the Model TP-2 for line scanning only and the Model TPA-5 for area or line scanning. The TPA-5 is





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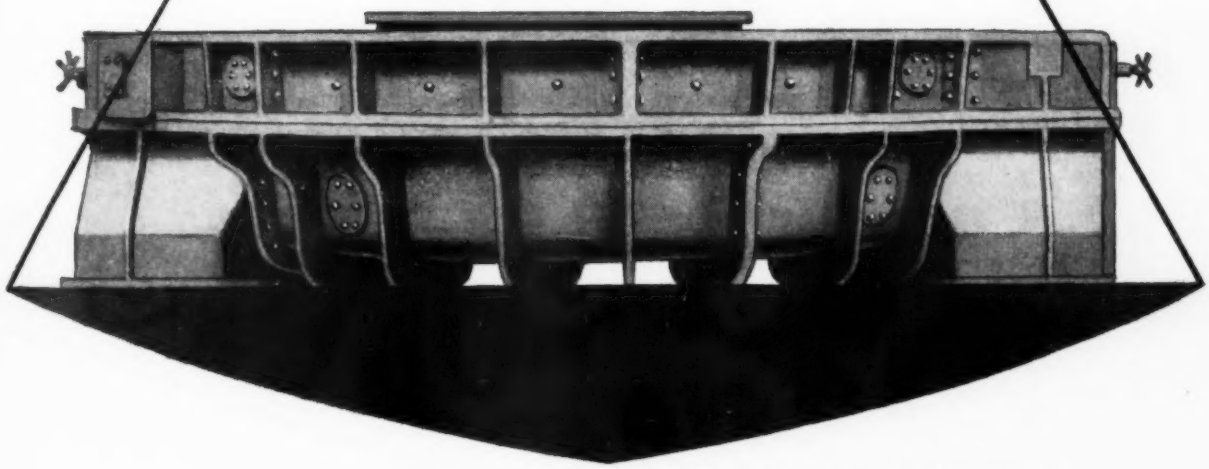

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generally required for scanning targets at about room temperatures, but may also be used for warmer subjects scanned at higher line rates.

The TP-2 is a linear scanner which produces a "temperature profile" over a narrow strip. Line rates may be selected from several seconds per line to 2000 lines per second, according to the application.

Resistance Thermometers

Other products in this field include resistance thermometers supplied with adhesive sensing grids or with grids suitable for riveting and cementing (Stikon) and an instrument mounted on a steel strap (Strapon) suitable for attaching to pipes and tubes. They are characterized by millisecond response, a high degree of accuracy and stability, and they will function from near absolute zero to 2000°F.

All these instruments are now available from **West Instrument Ltd., Brighton, Sussex.**

BCE 29 for further information

"Dolphin" Range of Vertical Pumps

This new range of pumps has been designed to cover a wide range of duties within three frame sizes with any interchange of impellers and diffusers to give any desired operating condition. The pumps were originally designed for marine duties such as salt and fresh water circulation, bilge, ballast, fire, etc., but they have also proved successful for such fluids as petrol, solvents, light oils, etc.

Capacities range from 60-2000 gpm with heads up to 300 ft and may be quickly dismantled by an inexperienced operator. The impeller is supported by a shaft running in a single bearing which may be grease or water lubricated. A soft packed gland or various mechanical seals may be fitted. Bearing and shaft can be supplied in corrosion-resistant materials to suit the pumping medium.

Suction and pressure gauges are fitted and self-priming or non-self-priming units can be supplied as required. **Hamworthy Engineering Ltd., Poole, Dorset.**

BCE 30 for further information

Bilton Gem Fresh-water Generator

This evaporator relies on vacuum to flash off the vapours from the feed water, which has been preheated by a heat exchanger condensing the steam from the steam-operated vacuum producer, and by another steam-operated heat exchanger.

Other sources of heat are from the vapours leaving the evaporator which condense as distillate, and from the heat in the blowdown water, which is bled periodically to minimize scale. All metal surfaces are treated with a special thick salt- and acid-resistant protective coating to prevent corrosion.

In the evaporation shell the vapours pass through a special variable-setting filter which controls the solids content of the distillate within a given limit without affecting the overall efficiency of the plant. Condensate and distillate pipes are of tinned copper.

The distilled water is sterilized in a chlorination plant or by means of ultraviolet light rays.

The sterilized water is then aerated, through a column packed with activated carbon and Iceland spar, and so rendered palatable. **J. B. Bilton & Sons Ltd., North Shields, Durham.**

BCE 31 for further information

New Publications

Plastic Finishes. Plastic finishes for all types of surfaces by the Plasinter process are described in a booklet issued by the Plasinter Co. Ltd.

In general, the company can offer a 7-14-day service for processing articles having specialized coating requirements. Protective coatings can now be applied to wood, brick, concrete and asbestos in addition to ferrous and non-ferrous materials.

The various P.V.C. and other coating systems are described in detail and there are a number of photographs showing coated products.

The book concludes with a description of the terms and conditions on which products are accepted for coating. **Plasinter Co. Ltd., Progress Works, Holyhead Road, Wednesbury, Staffs.**

BCE 32 for further information

Poly-V Drives. A very comprehensive publication on Poly-V drives, described as a new concept of power transmission, has chapters devoted to typical applications, engineering data, service factors, belts, horsepower ratings, pulleys, installation and maintenance and angle drives.

Among the many advantages claimed for Poly-V drives are that they transmit the same horsepower as conventional V-belts on narrower pulleys, there are no matching problems, longer lives of both belts and pulleys are realized, and quarter-turn drive losses are negligible because drag and chafing are eliminated.

A number of typical applications of Poly-V drive is illustrated. **Turner Bros. Asbestos Co. Ltd., Rochdale, Lancashire.**

BCE 33 for further information

Sintox Engineering Ceramics. This 36-page illustrated brochure covers the ceramic Sintox. Detailed information is supplied on all aspects of the material, including manufacturing methods, chemical compositions, properties, applications, etc. It is principally intended for those who need detailed information on all aspects of the material.

An 8-page version is readily available to engineering designers, research and development engineers, etc. **Lodge Plugs Ltd., Rugby, England.**

BCE 34 for further information

Steel Castings is the subject of a publication from Brown, Lenox & Co. Ltd. Details are given of the company's steel foundry and there is a useful table to help in steel selection.

Chapters on steel specifications, machining, sub-assemblies and product engineering are included. At the end of the publication, which is illustrated with photographs of a number of complex castings, there is an interesting glossary of terms used in the metallurgical and steel foundry industry.

Tables give comprehensive information about carbon, low and medium alloy steels, high alloy steels and steels for use in the chemical, petroleum and allied industries. **Brown, Lenox & Co. Ltd., Pontypridd, Glamorgan.**

BCE 35 for further information

Air Blowers. The latest brochure from W. C. Holmes & Co. Ltd., Publication No. 85, describes a number of modifications that have been made to the type RBS Holmes Connersville positive air blowers. The modifications give improved performances.

Principles of operation are briefly described in the opening paragraphs, and design features and advantages are also discussed.

The descriptions of the general construction and lubrication systems of the 5-, 6-, 7- and 10-in. models are given with line diagrams. A table gives capacities at listed pressures and speeds. **W. C. Holmes & Co. Ltd., Gas Handling Division, P.O. Box B7, Turnbridge, Huddersfield.**

BCE 36 for further information

Bellows Expansion Joints. A booklet issued by Chemetron Corporation on Tube-Turn bellows expansion joints is designed to provide users of this equipment with all the information necessary for engineering industrial piping incorporating these components.

The catalogue gives details of the results obtained from the company's extensive research programme which it undertook before it started to manufacture bellows expansion joints. The company believes that there has been a tendency to exaggerate claims for the anticipated service life of this equipment.

Useful tables giving the ratings of 50- and 150-lb joints are included. **Tube-Turns Division of Chemetron Corporation, Louisville 1, Kentucky, U.S.A.**

BCE 37 for further information

Suspended Idler Belt Conveyor Structure. A 10-page illustrated publication describes a noteworthy type of suspended idler and belt conveyor structure.

A feature of this equipment is that the idlers trough under load, thus reducing spillage with heavy loads. The tubular stringers may be adapted for carrying water for fire-fighting or other purposes.

Six standard sizes are available for carrying belts 20 in. to 42 in. wide. **The Mining & Engineering Co. Ltd., Meco Works, Worcester.**

BCE 38 for further information

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World of Chemical Engineering

Conferences

The Annual Joint Automatic Control Conference, which was conceived with the intention of reducing the overlap of conferences organised by different societies, has just now concluded. The sponsoring society this year has been the Instrument Society of America and considerable support has been given by the A.I.Ch.E. and A.S.M.E. in particular.

In all, some sixty papers were given, many of which covered fields of interest to chemical engineers. Included in the various groups were papers devoted to Optimal Switching; The Theory of Optimization; Hydraulic and Pneumatic Control; Economic Parameters in Process Control; Automatic Control Applications; Adaptive Control Systems; Statistical Design Considerations; Process Dynamics and others.

In the papers devoted to the Theory of Optimization was one by B. FRIEDLAND, which illustrated the design of regulators for a single plant with constraints upon either amplitude or energy of the actuating signal which minimize response time or integrated square error (ASME-61-JAC-1). In this same field MARKUS and LEE (ASME-61-JAC-2) considered the problem of various types of optimum controls for processes described by ordinary differential equations. Their approach provides a method of discovering whether an optimum control system can exist in the class of controls they considered.

In the section dealing with economic parameters, CHESTNUT proposed a number of cost models for systems engineering, and he gives data based on cost experience obtained in fields where mathematical relationship for costs are now being used. In another important paper entitled "Outline of the Future Role of Feed-forward Control in the Chemical Industry", CALVERT and COULMAN discuss the future role of feed-forward control in the chemical industry and they classify chemical processes and mechanical systems on the basis of tolerance levels and other factors. In another paper in the same group by ELIOT and LONGMIRE on incentives for computer control in the chemical process industries, the authors provide a standardized system of economic analysis which can be applied to any type of process in order to determine the areas of economic significance.

Finally, mention must be made of three papers on the subject of process dynamics. These were, first, "A Finite-stage Model for Highly Asymmetric Residence-time Distribution" by ADLER and HOVORKA; in this paper a finite-stage physical model is formulated which incorporates mixing and hold-up with the individual stages represented as interconnected perfectly-mixed and plug-flow units.

Other papers were concerned with the concentration dynamics in tubular flow systems with and without chemical reactions (FAN and AHN) and "Transfer Functions of Heat Exchangers" (HSU and GILBERT).

New Processes

A major breakthrough in gas reforming practice has been achieved by **Chemical Construction Corporation, New York**, with the placing on stream of a Chemico high-pressure reforming furnace operating at 250 psig. The scene of this development was the ammonia plant of the **Office National Industriel de l'Azote** (ONIA) in Southern France. Previously, reformers were operated at pressures below 175 psig and the innovation allows synthesis gas to be manufactured with a reduction in the compression machinery. Other advantages are improved heat recovery in the combined gas reform and CO_2 removal system, and in the carbonate CO_2 removal section new levels of regeneration efficiency are achieved.

A new process for the manufacture of isoprene was recently announced by the **Goodyear Tyre & Rubber Co.**, the details having been worked out by **Scientific Design Co. Inc.** So far few details have been released. Raw material is propylene and the new process permits the manufacture of a synthetic rubber at a maximum cost of 25 cents per pound.

In a quite different field—that of organic mercury compounds — **F. W. Berk & Co. Ltd.** announce a new process for diphenyl mercury. Here again, the new process has resulted in a considerable reduction in cost. Diphenyl mercury is widely used as an accelerator of polymerization reactions.

In the metallurgical field, what may be a very interesting process has been devised by two metallurgists of the University of Witwatersrand. The process is designed to treat manganese-containing effluent normally pumped to waste from uranium oxide plants. Output by this electrolytic process is somewhere in the region of 2400 tpa and plans are in hand to double the capacity.

Another new process manufactures high-quality copper from low-grade ores without a melting stage anywhere in the scheme. This process has been developed by the **E. W. Bliss Co., Canton, Ohio**, and a plant employing the process is to be erected in the Philippine islands by the Foster Wheeler Corporation.

New Plants

Refinery Activities

In the past months a number of refinery and petrochemical activities have been reported. In New Zealand, for example, construction of a £14-million refinery is soon to commence and the new plant will come on stream early in 1964.

The main equipment in the refinery, 15 per cent of the equity of which will be taken by **BP**, will include a crude distillation unit; a catalytic reformer; a gasoline treatment unit; a bitumen plant; and, in all probability, a gas oil hydrodesulphurizer. The initial output is expected to be in the vicinity of 2½ million tpa, made up of motor spirit, gas oil, diesel oil, fuel oil and bitumen.

At Martinez, California, **Shell** are building a catalytic treating plant for lubricating oil, while at Wood River, Illinois, a catalytic reforming unit is being built together with underground storage facilities for liquid propane. Additional crude distillation capacity is being provided at other Shell plants such as the **Shell Trinidad** refinery at **Point Fortin** and at the **Kawasaki refinery** of **Showa Sekiyu Kabushiki Kaisha, Japan**.

At home, plants are under construction for paraffin waxes at Stanlow and for the recovery of isopentane at Shell Haven, while at Pernis, in the Netherlands, a catalytic reformer and a treating plant for premium kerosine are now under construction.

Continental Oil Co., Houston, recently formed a new jointly-owned concern with **Deutsche Erdol. A.G. of Hamburg**, West Germany, to construct a "multi-million" dollar petrochemical plant near Hamburg. Jersey Standard's British subsidiary has a series of programmes under way to produce ethylene, propylene, butadiene and butyl, which go into synthetic tyres. Cost of the project, which will be completed in 1963, is about $28 million.

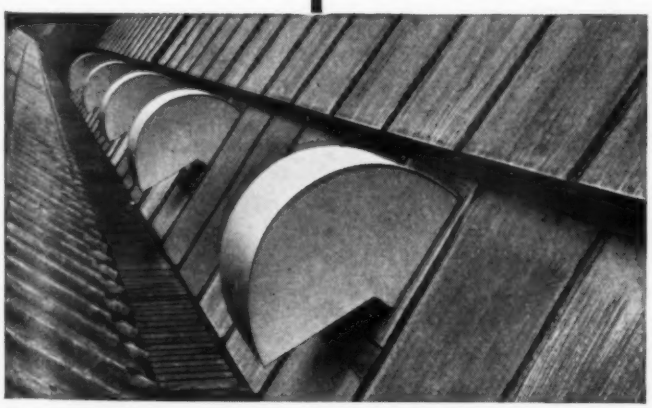
Italy is also expanding its petrochemical output rapidly, and near Gela a plant will be completed in September 1962. This refinery and petrochemical plant, owned by **Ente Nazionale Idrocarburi**, the Italian state oil monopoly, will produce 30,000 tons of ethylene a year, half of it going to make polyethylene plastic. The plant will also produce 60,000 tons of urea, 65,000 tons of ammonia and possibly over 100,000 tons of sulphuric acid.

Two further developments are worth noting: the first is the refinery to be established at **Barauni, India**, where the project, which originally envisaged an output of 1.75 million tpa, is likely to be considerably expanded as a result of recommendations made by the Russian engineering team who have studied the project. It is likely that this plant will be on stream with an output of 1 million tpa in the summer of next year, the output rising to 2 million tpa later.

Problem: **HEAT**

Solution: **COLT** Ventilation

Place: W. & R. JACOB (LIVERPOOL) LTD LIVERPOOL.



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For this, the 14th contract, Colt recommended a system of positive ventilation . . . 9 Colt CO 2046 Extractors to exhaust the peak summer heat load of 125,000 B.Th. U's per hour. Also, Colt Inflow Units to let fresh air in and create a draught-free movement of air.

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The second is the report by UOP of progress made in the application of electronic computer controls to refining and chemical processes. To this end a programme has been evolved between **UOP** and **Daystrom Inc.**, whereby a number of refinery processes are to be put under computer control. In addition, a computer-controlled petrochemical plant is expected to begin operation later this year.

New Plants for Fertilizer Chemicals

In this field a noteworthy development has been the **Kellogg-I.C.I.** process for the manufacture of synthesis gas from naphtha—a very valuable process for countries devoid of large supplies of natural gas but with good supplies of naphtha. This process will be the basis of the £6-million modernization of the Billingham synthesis gas plant and will see the replacement of the existing coke ovens.

Kellogg are building a fertilizer plant in Lisbon which will also employ the **Kellogg-I.C.I. process**. Kellogg activities include the construction of a vast nitrogen complex now in course of erection at Cherokee, Alabama. This plant, which is being financed by the town of Cherokee, will be released to, and operated by, the **Armour Agricultural Chemical Co.** There will be six different manufacturing plants on the 1200-acre site and the designed outputs in tons per day are: ammonia, 360; urea, 50; nitrogen solutions, 250; nitric acid, 300; ammonium nitrate, 250; ammonium phosphate, 500. The feedstocks for these plants will be air, natural gas, sulphuric acid, potash and phosphoric acid, the latter being supplied by the new Armour plant in Florida.

Among other plants in the nitrogen field is one now under construction by **Chemical Construction (G.B.) Ltd.**, London, for a complete new synthetic ammonia plant based on the existing coke oven gas source of hydrogen.

Of other fertilizer plants, phosphatic fertilizer solutions and industrial phosphates are additional products to be supplied by the **Electric Reduction Co.'s new** plant at Port Maitland, Canada. This $12-million plant is shortly to go on stream and its main product, triple superphosphate, will be manufactured at the rate of some 50,000 tpa.

New Plants in Other Fields

Other extensions recently carried through include those to the **Hedon Chemicals** vinyl acetate plant at Salt End, near Hull. (Hedon Chemicals is jointly owned by D.C.L. and Shawinigan Chemicals Ltd. (Canada).)

Whiffen's new plant for the manufacture of 350 tons of cyanuric and trichlorcyanuric acids each per annum is to cost £100,000.

W. G. Grace & Co. with a phthalic anhydride plant at Bogota and a butadiene-styrene resin and latex plant at Naples; a high purity hydrogen plant at Warrington for Laporte Chemicals Ltd. by the Power-Gas Corporation based upon the continuous catalytic reforming of butane with steam and a batch rectification tar acid column for Scottish Tar Distillers Ltd. by Chemical Engineering Wilton Ltd.

The latter company has recently designed and engineered the first continuous tar distillation plant in Australia and a naphthalene recovery plant to the order of the Australian Iron & Steel Pty. Ltd. The tar plant, which incorporates all the latest features of the Wilton system, will distil 215 tpd of crude tar and the naphthalene plant will produce 15 tpd of purified naphthalene. Both plants are to be erected by Simon-Carves (Australia) Pty. Ltd.

Ghana Petroleum Refinery

The Government of Ghana and the Italian company E.N.I. have signed an agreement concerning the construction of a petroleum refinery at Tema. Capital investment is estimated at £8.5 million and the initial capacity, which is primarily destined for export, is estimated at 1.2 million tons/year.

Contracts

A number of recent contracts also reflect the very great activity in the petrochemical and refinery fields. For example, **Fluor Engineering Co.** are to carry out the engineering for the **Svenska Esso** £7-million steam cracker to be erected at Stenungsund, Sweden, and work on the project is to commence very soon. The cracker, designed by Esso Research & Enginering, is for the production and recovery of ethylene and butadiene and it forms the heart of the Stenungsund petrochemical project.

Another joint venture for Sweden is the joint **Union Carbide-Fosfatbolaget** venture for a 35 million lb/year polyethylene plant to be built near Gothenburg—the first polyethylene plant to be built in Sweden.

A contract for the construction of a plant of 100,000 tpa of high-grade lubricants, to be built at the **BP Kwinana refinery**, has been awarded to **Foster Wheeler Ltd.** in association with **Constructors John Brown Australia (Pty.) Ltd.** This plant is expected to be in production towards the end of next year.

East Germany—Poland Contract

An agreement has been signed in Warsaw with the GDR for the construction of the oil pipeline USSR-Poland-GDR. According to this agreement, the GDR is to deliver part of the pipes for the section running from the Soviet frontier to the Polish town of Plock to the northwest of Warsaw, and all the pipes for the section between Plock and the Polish-GDR frontier. Furthermore, the GDR is to deliver equipment for the pumping stations along the corresponding sections of the pipeline.

To finance the construction costs, the delivery of the pipes and other materials, the GDR has granted Poland a credit of 57,825 million new roubles. The credit and the interest charges, amounting to 1.5 per cent annually, are to be paid back in the course of ten years, dating from the time the pipeline goes into operation.

Many other contracts reported cover a number of widely differing processes. **The Power-Gas Corporation** (Chemical Plant Division) are to construct for **Werkspoor N.V., Amsterdam**, three plants for the crystallization of high-purity urea, each one of which will produce 100 tpd by the Krystal process. These plants are to be erected in the Soviet Union.

Other equipment destined for the Soviet Union is some £200,000 worth of automatic control instruments manufactured by **Honeywell Controls Ltd.** This is required for a £2-million chemical works shortly to be put under construction by **Vickers Armstrong.**

Blaw Knox Chemical Engineering Co. Ltd. are to construct a fat splitting plant employing the Colage-Emery process for Price's (Bromborough) and, in addition, are to construct a polymerization unit for Bexford Ltd. at Manningtree.

The recently announced Stretford purification plant also figures in the contract news with an order for a plant for the complete removal of H_2S from 3 million cfd of coke oven gas. The plant is to be supplied by **W. C. Holmes** (Chemical Engineering Division) to the Northern Gas Board's West Hartlepool works. Hydrogen cyanide is to be removed from the gases before they reach the main Stretford plant.

Humphreys & Glasgow Ltd. have been awarded a £1 million contract for the design and construction of a gas plant at West Melbourne, Australia. The plant will comprise two gas-making sets and will be of the Onia-Gegi cyclic catalytic type. It will use heavy oil or refinery gas and its daily output will be between 10 and 15 million cu ft.

Asahi Chemical Industries of Japan, in co-operation with the **Austin Co. of Ohio**, have been awarded a contract for the construction of a 250,000 gallons per day brackish-water conversion demonstration plant in South Dakota.

Associated Electrical Industries Ltd. (Heavy Plant Division) are to supply synchronous and squirrel-cage induction motors valued at £120,000 to drive compressors in a new oxygen tonnage plant in New South Wales. The plant, which will produce oxygen in large quantities for steel manufacture, is being supplied by Linde Eismaschinen A.G. for Australian Electrical Industries (Pty.) Ltd.

Pipeline Advances

East German Machines for Oil Pipeline

Machinery for the pumping stations along the international oil pipeline which, starting from Kuibyshev (U.S.S.R.), will supply Poland, Czechoslovakia, Hungary and the GDR with this important raw material, are being manufactured by VEB Sachsenwerk Dresden-Neidersedlitz.

Two thousand miles separate Kuibyshev from the terminal in the GDR, the oil processing works in Schwedt-on-Oder. To transport the oil all this way, pumping stations have to be installed every 30 to 60 miles. They work completely automatically and only one man will be needed to service a station.

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